

Experimental Learning in Production Management

The effects of using
simulation games in
universities and industry

Edited by
Riitta Smeds
and **Jens O. Riis**



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Experimental Learning in Production Management

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Experimental Learning in Production Management

**IFIP TC5 / WG5.7 Third Workshop on Games in
Production Management: The effects of games
on developing production management
27-29 June 1997, Espoo, Finland**

Edited by

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Preface

This book is based on the presentations at the **Third Workshop on Games in Production Management, The Effects of Games on Developing Production Management**, held in Espoo, Finland, June 27-29, 1997. The workshop was organized by the Special Interest Group on Games of IFIP Working Group 5.7, which is coordinated by Professor Jens Riis. The Special Interest Group aims to enhance learning in production management in academia and in industry, through the development, application and research of simulation games. Currently, the Special Interest Group is developing a catalogue of games in production management, which will be available on the Internet.

The two previous workshops of the Special Interest Group were held in Aalborg and in Sønderborg, and a workshop and exhibition of simulation games was arranged in connection with the APMS '96 Conference in Kyoto in November 1996. In these workshops, various simulation games have been presented, experimented, and discussed, and experiences exchanged. As a result, a network of researchers and teachers interested in games has been created. The third workshop with participants from ten countries further expanded and strengthened the network, and created ideas for potential joint research projects in simulation for learning in production management.

The workshop was sponsored by the IFIP Working Group 5.7 on Computer Aided Production Management Systems, Helsinki University of Technology, the Finnish Graduate School of Industrial Management, and the City of Espoo, which we gratefully acknowledge.

We want to thank for the support of the other Programme Committee members Professor John Johansen, Southern Denmark Business School, Associate Professor Inger Eriksson, Swedish School of Economics and Business Administration, D. Tech. Eila Järvenpää, Helsinki University of Technology and M.Sc. Päivi Haho, Neles-Jamesbury Group Ltd.

Thanks are also due to the other energetic and creative members of the organizing committee Lic. Tech. Minna Forssén-Nyberg and Lic. Tech. Matleena Pankakoski, Helsinki University of Technology, as well as to the valuable secretarial support of Saila Karmala.

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Editors

Introduction

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Games and simulations are great methods for experiential learning in production management. They create awareness, understanding, and new knowledge about complex production systems that would be very costly, even impossible to gain in practice through trial and error. For students, the simulations are a very effective way of experiencing and understanding conceptual theories and to prepare for the challenges of the professional engineer. For companies, simulations and games provide a unique possibility to experiment and learn future process designs before implementation. For researchers, simulations offer a superior method to "experiment" in laboratory settings the behaviour and development of complex enterprise systems.

The experiences, and thus also the learning effects of the games, depend however critically on the game model. In addition to manual "hands on" games played through human players in the same physical location, we can apply advanced telecommunication technology to create simulation environments. Many of the chapters in this book discuss the possibility of applying advanced information technology in the games; from Cyberspace simulation through the Internet Model Factory and the Enterprise Simulation Laboratory, to telematic CSCW planning of factory layout, and interactive multimedia simulation of individual operator work. Modeling a game to resemble reality well enough to give right experiences is a tough challenge, which is even aggravated when we use software models. The research on the **effects of games on learning** is thus of great importance. This book addresses the issue on many levels.

The book covers two main application areas for games in production management: education and industry. The borderline between these two groups is vague. Educational games are generic, they illuminate the production management concepts and the dynamic functioning of a modeled, fictive production system. These games can also be well applied in companies to create awareness and understanding e.g. of new production management principles. But in addition to this, companies request tailored games that can be used to simulate their specific systems. These tailored games can on the other hand become "generalized" to some extent by supporting the design and running of the games with a methodology.

The book starts with the **simulations and games in industry**. To build a creative tension, we begin with the future possibilities of cyberspace and virtual reality to support simulation and experiential learning. *Mike Uretsky* discusses the challenges and threats of simulating in the cyberspace. Since the complex systems we aim to understand exist more and more in electronic networks, simulation may be the only alternative method to comprehend them. We have therefore to research carefully the validity and learning effects of these models.

Riitta Smeds presents the new concept of the Enterprise Simulation Laboratory, which is currently being developed in a multidisciplinary research and development project at Helsinki University of Technology. In the Laboratory, a "virtual enterprise space" will be built, which will enable the use of three-dimensional graphical models for the visual, interactive simulation of both generic and enterprise specific business processes. The Laboratory enables unique possibilities to empirically study simulation techniques, the dynamics of enterprise systems and the experimental learning of organizations.

Experiences from tailored simulation games in the development of business processes are discussed by *Päivi Haho* in the context of re-engineering order-to-delivery processes in manufacturing enterprises. *Minna Forssén-Nyberg and Päivi Kutilainen* report simulation cases from a printing house and from food industry. Both these chapters present applications that aim at creating process-oriented change: experiences are reported from the effects of the games in process development projects from analysis and design until implementation. *Matleena Pankakoski* presents an efficient methodology to disseminate the tailored simulation game methods to a cluster of companies and to facilitate inter-organizational learning.

Jörn Nilsson has researched an enterprise specific simulation "game", an interactive, multimedia simulation environment for an individual operator working in a complex, computer controlled chemical factory. The simulation tool allows the operator to create unexpected problem situations and to train how to handle them. The tacit knowledge of the operator is made explicit in the simulation, and can be stored through video recording for further analysis after the game.

The second part of the book, **simulation games in universities**, starts with the future a well, by introducing the Model Company concept. This novel idea is presented by *Jens Riis, Uffe Thorsteinsson, Ari Barfod and Erik Lyngsie*. The Model Company is a generic platform for factory experimentations, located on the Internet. The platform consists of a comprehensive data base of the fictive Model Company, and a set of tools to be used in the analysis, design and implementation of the experiments, that the players are conducting to develop it. The leaders of the game impose problems or incidents on the Model Company, and the players act in

teams to solve the problems, applying the platform data and tools. Real-life managers, using their industry experience, "simulate" the Board of Directors of the Model Company and give feedback to the players on the probable effects of their solutions.

The real-time participator-simulator, presented by *Alastair Nicholson* creates a fictive model organization as well, but instead of a data base it is a physical layout, with its processing logic, and a real-time control and display system. The students play different roles of worker, proposer and manager, and reorganize the company to represent new managerial principles: JIT, MRP or cellular organization. The players test and evaluate their solutions, the new layout and flow structures, job definitions, and control systems, and experience the difficulty of imposing new management principles on people who have no knowledge of them. Through the comparative simulations, the students can see how the systems manage the operations and how the manager manages the system, and thus achieves the ability to "manage complexity simply".

Harald Augustin presents a novel factory planning simulation in a distributed global organization, realized through telematics and computer supported co-operative work. The players are students in a network of universities, situated in different geographical locations. Their simulation task consists of designing together a plant layout for a factory, based on real data, interactive team problem solving through ICT, and the usage of distributed knowledge. The simulation aims to create an understanding of the possibilities of ICT in distributed cooperative work. The chapter discusses first results from the game runs in summer 1997.

Gert Zülch, Uwe Jonsson and Andreas Rinn present a generic, computer-based simulation game for the redesign of production systems. A fictive bicycle company's production system is analyzed, simulated and redesigned applying a three phase, software supported seminar on Production planning and control, Production controlling, and Redesign. In each seminar phase, the production plans created by the players are run and evaluated in monetary and logistic terms. The software modules allow to trace the simulation quantitatively, which helps to detect areas for improvement: redesign of the work organization and outsourcing. The main objectives of the game are to create an understanding of a generic production system, and to find solutions for better performance through re-engineering. This generic game also highlights the benefits of the simulation tool.

Karsten Schierholt and David Brütsch present a generic, manual logistics game, played by teams of students in the introductory course of logistics. Its aim is to create an understanding of the organizational aspects of the complex logistics system. The game is physically constructed as a board game of manufacturing toy brick products. Its initial layout is functional and Tayloristic, and production is run according to given rules. The calculation of production costs reveals weak points in the system, and new layouts are developed and experimented by the players during successive development rounds. The authors compare the solutions of three student groups qualitatively and quantitatively, and relate them to the game results.

Also *Lotte Alstrup and Lise Busk Kofoed* highlight in their game the drawbacks of the Tayloristic production process, and give for the players another scenario for experimentation: the anthropocentric "Developmental Work" approach. Through the two different game scenarios and by using reflection as an essential part in

achieving learning through the games, they increase the engineering students' awareness of working environment issues.

The last educational game of *Karel Mulder, Karin Ree and Henk Mulder* deals with strategic and political issues: the environmental effects of product innovations in industrial R&D and production planning. The players represent the Corporation, Government, and the Press. The engine in the game is a computer model that calculates the fictive Corporation's financial results based on its investment, price decisions and simulated demand. But the main point in the game is the negotiation of the Corporation's strategy process, affected by the power debate between Government and Industry. The game promotes learning about such vital themes as trust, delegation of responsibilities, and decision making under uncertainty.

In the concluding chapter, *Jens Riis and Riitta Smeds* present the results from the many team work sessions and group discussions of the intensive "working workshop". The simulation games offer many possibilities to enhance learning in new production systems. At present, industry is faced with rapid globalization, telematic networking and integration. These new trends put demanding challenges on the design, operation and validation of simulation games.

The book shows a wide spectrum of successful existing games in production management, and presents development ideas for future simulation games. The research on the effects of the games on learning in production systems has only begun, and has to be intensified so that simulation games and methods can further be developed to increase the efficiency of experimental learning and innovation in production systems.

PART ONE

Simulation Games in Industry

Importance and Use of Simulation in a Cyber Environment

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Abstract

The thesis is very simple: Simulation is the future! Growing environmental complexity leaves few alternatives to the use of simulation for planning, controlling and training. We can stipulate the existence of a cyber environment. There are few who would question the fact that more and more of our activities are dependent upon both sophisticated, interconnected models and computers on which to execute them. Moreover, attendant with this growth are an increasing number of practical operating problems and risks. The thesis of this paper is that simulation offers one of the most fruitful ways to address these issues. Indeed, increasingly, simulation may be the only way to effectively address them. If one agrees with this conclusion, it follows that there is a research agenda that must be implemented to resolve critical open issues.

Keywords

simulation, training, computers, research

1 INTRODUCTION

The thesis will be developed in the following manner. We begin by briefly reviewing critical dimensions of three related areas – the cyberspace environment and activities taking place within it, simulation and gaming, and human learning and performance. Using this survey as a basis, we will move on to show that growing system complexity carries with two major problems with it – people become increasingly removed from systems they use and problems will inevitably happen. Simulation appears to be one of the more fruitful tools for addressing these problems. At the same time, there are clear gaps that must be filled in before this potential can be realized.

2 BACKGROUND - SELECTED PIECES

Examining the role of simulation in addressing cyberspace problems requires that we agree upon the nature of the environment, the capabilities of simulation, and how these factors relate to our human behavior.

2.1 The Cyberspace Environment

The thing called cyberspace represents both little change from the past and simultaneously radical departures. As a practical matter, the computer-based environment has been present since the early '60s. We have been evolving towards larger and more complex computer-based systems that are increasingly interconnected. With the rapid growth of the world wide web, the changes have become so great and rapid that they have the potential for altering some of our most fundamental assumptions about our environment and the ways with which we interact with each other and this environment.

Growing Automation and Dependence Upon It

We live in a computer-based environment. Literally every aspect of our lives depends upon or is impacted by computers. Every device we use, from watches to televisions to cars to medical diagnostic equipment, depends in one way or another on computer chips that have been embedded within them. At the other end of the spectrum are large-scale, so-called mainframes, that are used for everything from meteorological forecasting to high volume transaction processing. In between are, of course, the ever present notebook and desk top computers we all use to carry out our daily business.

These computers are used for everything from word-processing, to spreadsheet-based analyses, to execution of highly complex, sophisticated mathematical algorithms. Unlike the past, most of the programs are bought from independent vendors, presumably because of their functionality. (I say *presumably*, because few of us actually run adequate functionality tests). The important factor is that, unlike past practice in which we wrote our own computer programs, we now rely upon software written by other people. Even where we develop our own modules, we are likely to embed code modules developed elsewhere. Stated differently, we are using computer code developed by other people and we are assuming that the

people are competent, that they have adequately tested their product, and that it satisfies our required functionality.

And finally, the models and the computers are interconnected. Computer models pass data to other models and to users. In the same sense, computers communicate with each other over short or long distances – and without any significant human intervention.

Network is the Focus

As significant as any of the above features might appear, they have now lost their real significance. Most observers have shifted their attention away from the individual components mentioned above, to the relationship between them. Stated another way, *the future is in the network, not the computer!* When viewed from this perspective, The computer, is just one specialized component within the bigger picture.

There are two very separate views of this inter-connectivity. Consider the world wide web as one example. From the perspective of the user, inter-connectivity has only three components, i.e., the user, the browser, and content of the sites accessed through the various search engines.¹ All of this is independent of the fact that from the scientist's perspective, everything is dependent upon a complex, ever-changing infrastructure and network topology.

The concept of inter-connectivity is not new. EDI has been around for many years. The essential point is that, with the web, inter-connectivity has become so common, that nobody cares about the individual components.

It is essential to recognize that the automatic electronic transfer of data between different modules or locations has the effect of creating tightly a tightly-coupled system. In such a case, the output from one module are transferred to another, with little opportunity for human intervention or at least implicit quality control.

Complexity and Ignorance

The systems we are using have gotten larger and more complex. Each individual module is larger than it's predecessors. Increasingly, these modules utilize complex programs or concepts that are beyond the immediate knowledge of the professionals using them. And finally, the modules are inter-connected with others – at the same locations or elsewhere. The systems are increasingly big and complex. All of this means that users are less able to understand the tools that they are using – which may be acceptable if the tools work (and you know they are working satisfactorily), but certainly not in times of difficulty.

Virtuality

What you see is what you get. Since the network is the dominant factor, one is almost always dealing with entities that are geographically located someplace else. This focus shifts away from the physical and reality is thus largely a function of abstract or second-order perceptions. In this sense, an organization exists because it is on the network, has a site and called an organization – virtual firms, virtual

¹ The computer, *per se*, has been omitted, since it is functionally transparent. While we are using personal computers today, we may well be using telephone devices, cable television, or what is called in the US, WebTV.

organizations, virtual shopping malls, etc. They have many of the characteristics of their counterparts, but they may or may not have real physical existence. As a practical matter, this means that one can be dealing with virtual employees, organizations, or firms. A location on the web can be more important than a real physical location. And finally, the fact that existence lies in a virtual reality introduces new concept in alien behavior. A person or organization can literally be doing business in a country, without being physically present, even though performing these same activities in person might be illegal. A visitor to a web site can be just as unwelcome as he or she might be in person.

Fluidity and Fast response

Constant change is the norm. The world wide web is constantly and speedily evolving. New organizations are forming and disappearing. The old idea of products with multiple year expected lives is rapidly being replaced. The ease of product creation and market entry creates competitive forces that shorten a product's expected life to well under a year. The speed with which things change puts a premium on fast response, delivery and adaptation. In some ways, management of information about economic activities can be just as (more) important than the activities themselves.

It is difficult to set long term directions in a period of fluidity and fast response. The financial markets (and the press) look for immediate indicators of good and bad performance.

Trust issues are common denominators

The environment described above carries with it a large number of unsolved and evolving issues. The resolution of these issues will form the basis for the coming age of electronic business.

A natural by-product of the previously noted phenomena is growing concern with trust-related issues. Without trust, there can be no real reliance – and growth. The trust issues come in many forms. While it is beyond the scope of this paper to deal with electronic commerce or trust per se, enumerating some of these areas does serve to highlight the breadth of concerns.

- *Security.* There is a constant stream of articles regarding security violations associated with web use. While there are certainly important technical issues, the most crucial concern is the lack of trust in the systems being used. Credit card use on the Internet is one example. There are many articles about the possible theft and misuse of numbers. At the same time, from a realistic point of view, the incidence of these events is extremely rare and you are probably safer using a computer-based system than giving your credit card to someone over the phone or in a restaurant.
- *Contracting.* There are a broad range of what might be called contracting issues. The legal structure is just evolving. There is currently no electronic concept of a notary public. There is no agreement about the location of the transactions. (If you are in New York accessing a gambling casino in the Bahamas, where is the transaction taking place? Are you violating any laws? Do you know what laws are applicable?)

- *Intellectual property rights.* Who owns your ideas and how can you protect them. Some countries, such as the United States, have very well-defined, restrictive concepts of ownership embedded within their patent and copyright laws. The rationale is associated with providing economic incentives to encourage innovation. Other countries, particularly developing nations, view free distribution of things like software as being more important than the protection of developers.
- *Organizational change.* The web is eliminating the need for middle level workers. (It may not be actually eliminating the workers, since union regulations act as a strong retarding force in some countries). This is a very important point and one that comes to the heart of our thesis. Eliminating middle level workers flattens organizations. It creates virtual organizations, with workers located in many different places – often not available when they might be needed. Thus, in a time of increasing complexity, we are increasingly working with distributed knowledge and workers who may not be available when they are needed.

2.2 Simulations

A simulation is a model. It is designed to represent the important characteristics of some system. Underlying this simple statement lie a number of important assumptions.

- A simulation is a representation of something. It is not the thing itself.
- To be useful, the simulation must represent the important characteristics of the thing being simulated. This means that a particular use is contemplated and that someone has made a value judgment regarding the features that are and are not important. This is a very important set of decisions, since they drive the tests needed to validate the models. A model being used for training purposes need only have sufficient face validity to cause the trainees to behave in the desired manner. In contrast, the model being used for forecasting or decision-making purposes must have all of its underlying assumptions tested (individually and together) and validated.
- From a conceptual point of view, the form of the simulation is irrelevant. It does not matter whether it is a role playing exercise or a more formal attempt to get at model-generated 'what-ifs.'

Traditionally, most simulations have existed within academic frameworks. This is changing, we are now seeing an increasing number of them used within business contexts. Subject to the above noted caveats, they can be used in industry when one or more of the following conditions are satisfied:

- It is essential to collapse time, permitting experimenters or participants to get immediate feedback on their potential decisions.

- The only way to test a system is through simulation. Pilots and nuclear plant operators rely heavily on simulation-based training in critical events because other alternatives are either not feasible or ineffective.
- The cost of doing a simulation is less costly than the cost of dealing with reality.

3 CYBERDOOM: RISK-RELATED ACCIDENTS

The risks associated with modern systems are bound to remain. Moreover, as low as the related probabilities might be, we need to take any feasible steps to mitigate the expected damages.

Note that the above comments are premised on an assumption that the risks are unavoidable. This is consistent with the line of reasoning presented by Charles Perrow (1984). His line of reasoning was very straight-forward:

- All systems (and their component modules) can fail. There is no such thing as a fully debugged module. Indeed, within the computer environment, we are even limited in our ability to measure reliability in any meaningful sense.
- Systems grow and as they grow, they get more complex. Systems are rarely smaller and simpler than their predecessors. We build systems by adding features and combining previously separate modules. As the models get larger and connected, the number of possible combinations increases.
- Automation of systems makes them more tightly coupled. One of the features of automation is the linking of previously separate modules. This means that information from one module is automatically transmitted to the next automated module – thus eliminating opportunities for traditional, human, supervisory review, prior to use of the data by the next module. Stated another way, an error in one module will be automatically transmitted to the next. Unless someone recognized the error in advance and made provision for handling it, it will likely be used!
- As system grow and get more complex, they get less understandable. A large system is less understandable than a smaller one with fewer features. The lack of understandability is a function of two factors. First, the large number of components and component features strains the ability to keep track of everything and understand both the components and the entity as a whole. And second, the large number of people involved with the design, implementation and operation of these systems introduces organizational problems that also reduce the ability to understand what is taking place – and why.
- Early symptoms of system problems are either missed or discounted. Some early symptoms of problems are bound to be missed. Some may simply be missed because the operators are focusing elsewhere. Some may be below the thresholds causing us to focus on them. Some may be missed because the operators lack the experience to recognize them or evaluate their significance.

And finally, others will be implicitly missed, because they are ambiguous and the operators take a ‘wait and see’ approach rather than take the consequences of taking what might be untimely corrective action.

- And finally, the ability of organizations to deal with these problems is limited by their own structure and behavior. Given that the problems are recognized, organizational forces will cause corrective action to be, at best, delayed while damage continues. This phenomenon is found in many different contests – “It’s not my job.” “I’m looking for my supervisor.”

The bottom line is quite clear, accidents will happen – probably with less frequency than in the past – and when they do, they will be serious. There is no shortage of examples of these phenomena – Three Mile Island, Bophal, Challenger, and on and on.

I am very concerned about this situation. I think that is more serious than might appear on the surface. We are producing managers who enter the managerial ranks without developing the experiences (intuition) gained as a by-product of working one’s way up the ranks. We are using managerial work stations with imbedded technologies that are not, and cannot be, understood by their typical users. Intelligent agents and genetic algorithms are giving some web-based modules the ability to change and mutate without human intervention. And finally, we are producing managers who view the use of technology in the same way we all view using a car. (You turn the key and it works. Moreover, using it does not require understanding all of its component parts).

4 BRINGING IT TOGETHER: DIRECTIONS FOR THE FUTURE

The thesis of this brief paper is that simulation should be looked at as an increasingly important tool for addressing the kinds of problems discussed above. While one could make a case for the fact that this is the most cost-effective approach, it is equally reasonable to say that it is the only real alternative. This observation is based on the fact that, much as some people might like, systems will continue to be increasingly large, complex, and automated. We will also never return to an environment in which people literally work themselves up the ladder from the loading docks. Intuition based on experiences having a physical reality are largely gone and they will not return.

The ability to use simulation to address these problems is present, but it has yet to be adequately developed. Three sets of capabilities must be present to make meaningful progress: (1) an ability to develop adequate and appropriate simulations, (2) an ability to run these simulations properly, and (3) an ability to adequately evaluate their results.

- *Development.* We have the ability to develop simulations. There is a respected literature on simulation and game development. While much of this literature is anecdotal and it is dispersed over different disciplines, it does exist and appears to be serving its audience adequately.

At the same time, we have not ratcheted up our development capabilities adequately. Most computer-based simulations and games are still written in basic computer languages, like Visual Basic and Access. And we have failed to take advantage of the broad range of developmental efficiencies associated with object-oriented approaches. This development is essential, since it permits moving and embedding knowledge into new applications.

- *Running.* There is a body of professionals who have experience in operating simulations. These professionals are dispersed over different disciplines – operations research, engineering, sociology, and business management. At the same time, it is equally useful to recognize that, in spite of the existence of clusters within lots of organizations, there is no generally accepted gathering place for professionals in this area!
- *Evaluating.* As shown below, there has been relatively little formal work associated with validation of the simulations *and* their results. Unfortunately, the quality of work done to date has been open to serious question – my opinion. This gets at the heart of the trust issues noted above. If we, as professionals, cannot provide adequately defensible validation data, we are relegated to be just another striving group of disciples – and like similar groups in the past, often unheard or ignored.

We need to address several critical issues if professions, like this, are to realize their critical roles in future economic developments.

- We must deal with the honest observations that, outside of engineering and academic sociology, there is not general acceptance of this approach.
- There are no agreed upon texts or guidelines or standards.
- This is not yet a recognized academic or business discipline or are of expertise. It should be, but it is not yet there.

In brief, we have a long way to go. I do not question the need for progress. Indeed, I hope I have made a case for simulation as an essential management and research tool in our rapidly changing web-based environment. At the same time, while some of the underlying methodology is present, there are a large number of issues that must be addressed adequately before real progress can be made.

5 A RESEARCH AGENDA

Assuming that one buys into my assertion that simulation is a critical tool for future management and training, there are a large number issues that must be addressed. The following research agenda has its origin in a list provided in Greenblat and Duke (1975). They point out that a large number of assertions have been made in the literature regarding the potential benefits associated with simulation-gaming for training purposes. Their list is broken into the following major categories:

- Participant motivation and interest
- Cognitive learning
- Impact on the character of later course work
- Affective learning regarding subject matter
- General affective learning
- Changes in classroom structure and relations

Each of these categories are subdivided into more pointed sets of topics within the original source. Elaborating upon them is beyond the scope of our immediate effort and you are directed to the Greenblat and Duke material.

The critical point regarding these potential benefits is that they are allegations or hypotheses awaiting further testing. Little respectable progress has been made since the '70s!

Going beyond the training and education environments requires addressing a broad range of far more serious questions.

- *Model validity.* Training and educational use requires only that the models have face validity. They must be adequately believable by their users. Adequacy, in this sense, is measured by the fact that people respond in an intended fashion. Any decision-making or predictive use of simulation requires that one be able to guarantee structural validity and predictive ability of both the model and data. This ability is easier in straightforward simulations that are mathematically oriented, than in complex simulations with large behavioral components.
- *Impact - the final frontier.* If simulation is to be a meaningful and relied upon tool in the cyber environment, we need to answer some very important and immediate questions.
 - * What effect will it's use have on organizational performance? Will people who use simulations be able to communicate and operate within organizations more effectively than others? Will they have more empathy and understanding of those around them?
 - * Will people who have used simulations be able to generalize their knowledge into new and somewhat different situations?
 - * Will people who have used simulations be able to respond to emergencies – especially those requiring fast response time and dealing with complexity, areas calling for a high degree of intuitive behavior?

Simulation, on paper, is a very powerful and useful technique. It has the ability to help managers address some very critical issues. Indeed, it may be the only approach available in many cases. At the same time, practitioners of this field have a long way to go to validate the value of their tools. This paper has briefly outlined the environment and the need. The issues listed are just the tip of the iceberg. Add to them and address them.

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7 BIOGRAPHY

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Enterprise Simulation Laboratory for simulation games in virtual reality

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Abstract

The paper presents the Enterprise Simulation Laboratory concept, which is currently being developed at Helsinki University of Technology. At first, the need for visual, interactive enterprise simulation models is put forward. Thereafter, a classification of enterprise simulation models is presented, and the state of the art in enterprise simulation games is analyzed. To fill the gaps in both manual and computer supported enterprise simulations, the idea of a "virtual enterprise space" for simulation is presented. It enables the interactive, visual simulation and experimentation of enterprise systems in a group mode. The Enterprise Simulation Laboratory creates unique research possibilities to apply and study enterprise simulation techniques and organizational learning in a laboratory setting.

Keywords

**enterprise simulation, virtual reality, games, experimentation,
organizational learning**

1 THE NEED FOR ENTERPRISE EXPERIMENTS THROUGH SIMULATION

The way an enterprise is "seen" and understood is fundamental for its management as well as for research. However, enterprises are not stable structures, but change as a response to the rapid development of their competitive environments. This poses the challenge for managers and personnel, as well as researchers and students, to continuously learn and update their mental constructs of enterprises.

Traditionally, industrial companies were perceived as mechanistic systems of functional departments, controlled and managed through the hierarchy of authority. This Tayloristic organization, however, leads today often to sub optimal business performance. This was demonstrated in the 1980's by the superiority of the new business process oriented "lean production" perception of enterprises and enterprise networks, when compared to the old Tayloristic organizations.

Lean management was innovated through painstaking incremental experiments in Japanese companies, starting already in the 1930s. Costly trials and errors helped managers in car industry to understand the enterprises' operational functioning as organic processes rather than as mechanistic functions, and to develop innovative process-oriented management principles (e.g. Schonberger 1982). The lean enterprise was "benchmarked" and adopted by the follower companies, to become a new management paradigm. (Smeds 1994)

At present, new images of industrial enterprises are gaining ground. To answer to increased competition, enterprises have now to be agile: effective, flexible and innovative at the same time. They have to learn and innovate continuously, and evolve in close interaction with their turbulent environment (e.g. Senge 1990, Wheelwright and Clark 1992, Nonaka and Takeuchi 1995, Smeds 1996). The new management implications of this image are however again hard to understand, by managers as well as academia. How does an agile, continuously learning enterprise look like? How does it work? How should it be organized and managed?

Enterprise experiments to create more competitive processes are constantly conducted in companies, and researchers are analyzing and explaining, why they succeed or fail. But trial and error is slow and ineffective, and errors in real life can be fatal. For product innovations, scale models and even virtual prototypes are used for testing out different product concepts before expensive realization. Analogically, for "enterprise innovations", *simulation models* are needed that allow "enterprise prototyping", the experimentation of an enterprise's organization, its operational processes, strategies and the resulting economic performance before final design and implementation (Smeds 1996, 1997, Riis et al. 1996). To complement and support the "real life learning" in companies, *simulations on enterprise models* are needed.

2 MODELING ENTERPRISE SYSTEMS FOR SIMULATION

2.1 Technical and social systems

Enterprise simulation models can be classified according to the *nature of the system to be simulated*, and the *tools* used the simulation (Figure 1). For example material flows and layouts of complex production systems, as well as economic systems, are often modeled as *technical subsystems* of the enterprises. They can be simulated with computer supported mathematical models. Production scheduling simulation packages for companies, as well as software games for education are examples of technical enterprise simulation models. Simulations on the technical models are run by experts, and the outputs can thereafter be used as input in the human decision processes or for training.

Figure 1. A classification of models to simulate enterprise systems

The third dimension to the classification of enterprise simulation models comes from the fact that the technical as well as social simulation models can be either

Generic simulation models simulate the behavior of fictive enterprise systems. They can be used for educational purposes, to create awareness and understanding about the general dynamics of enterprises, about new management principles and concepts. Examples like computer supported business games, manual board games and role plays with pedagogical manuscripts are of high value for the education of students, and they can also be used for education of enterprise personnel.

An *enterprise specific model* is tailored to support the experimentation, development and testing of a specific system of a certain company. Examples are technical layout and material flow simulations, or social simulation games for business process development.

3 SIMULATION GAMES FOR SOCIO-TECHNICAL ENTERPRISE SYSTEMS

A *simulation game* combines the features of simulation (incorporation of the critical features of the reality into the model) with those of a game (players, rules, competition, cooperation) (Saunders, 1988). The game component adds the *social dimension* into the simulation model.

An enterprise simulation game is based on a simplified and accelerated model of a selected *enterprise process*. This model is often physically constructed e.g. on a game board or in a simulation room. The game model and rules should be in relevant aspects as isomorphic with the real process as possible, because they direct and restrict the understanding created by the simulation.

The most important elements in the simulation are the *players* of the game. The dynamic operation of the process is simulated through their *action and communication*. Thus also the composition of the *game group* is important. The simulation games are often facilitated by one or several *facilitators*.

3.1 Generic enterprise simulation games

Generic enterprise games are often based on a *manual model*. For example a production system game can be built of a game board, physical material, written rules and documents. The game is played according to the rules by human players occupying fictive roles (e.g. Schierholt and Brüttsch, in this volume, Alstrup and Busk Kofoed, in this volume). Some of these generic games are available as commercialized products, e.g. ADVANTIG (Gertsen 1995), and the Lego Truck Game (Johansen and Mikkelsen 1995). A facilitators typically assists in the game runs and discusses the results in the debriefings together with the players.

To a growing extent, the economic calculations and the technical subsystem simulations during the games are conducted on *computer-based mathematical models* (e.g. Zülch et al., in this volume, Mulder et al., in this volume).

Generic *business games* are frequently used in university education. They simulate the economic performance and competition of companies based on mathematical computer models. Through the inclusion of *team work* and seminars into decision making and reporting during the game, the social dimension can to some extent be incorporated into the basically very "technical" business simulation. (e.g. Smeds et al. 1996)

3.2 Enterprise specific simulation games

The enterprise specific simulation games are based on tailored models of company processes, and on company data. Typically, a rough model of the process is first created as an analytic description (flow chart) of the activities and the information and material flows. Then it is *manually constructed*, e.g. by furnishing a seminar room as a "scale model" of the process, with adequate paraphernalia and process materials. In the game itself, the players fill in the relevant details and much of the coordination and cooperation rules of the enterprise process.

The composition of the game team is important for the validity of the simulation model. The team should mirror the organization of the process as closely as possible; ideally all employees and managers engaged in the real process should participate also in the simulation. The players act in their own work roles. They *act and "talk through"* the activities and information and material flows of the process, following the route of a concrete case example, e.g. a specific customer order, and using supporting case material. *Observers*, e.g. support staff from the company's development functions, representatives from other departments or organizations can participate in the game and in the discussions, depending on the focus of the game. If top managers participate in the game, also the strategic and policy aspects of process operations can be included in the simulation (e.g. Smeds 1996).

Through the human interaction and discussion in the game, tacit knowledge of the process is externalized and shared, and a common understanding is created. Development ideas, problems and open questions concerning the process are awakened and written down for further use in smaller process development teams. The teams refine the ideas into a new process design to be tested in a prototyping manner in the subsequent simulation games (e.g. Smeds and Haho 1995a, b, 1996, Haho and Smeds 1997a, b, Forssén-Nyberg and Hakamäki, 1997, Ruohomäki 1995, Haho, in this volume, Forssén-Nyberg and Kuttilainen, in this volume, Pankakoski, in this volume).

Enterprise specific simulation games are efficient methods for process innovation (Smeds 1994, 1996). Therefore the choice of the target process and the objectives for the process "prototyping" should be based on strategic analysis. Sometimes, the first simulation game becomes itself an important method to clarify and define the strategic objectives for the process re-engineering project. (Smeds 1996, 1997)

Although the models of enterprise specific games are tailored, the methods and procedures for building the models and for running the games can to some extent be standardized (e.g. Piispanen et al. 1996, Haho and Smeds 1996, 1997a, b). There exist also enterprise specific games, where the technical subsystem simulations are run on a *computer model*. This enables an accelerated simulation e.g. for capacity planning in the production process (e.g. Savukoski et al. 1995).

3.3 The need for new tools to support simulation games

The *social simulation* that is necessary in both the generic and specific enterprise games is achieved through human *interaction, discussion and experimentation* during the game. But the ways in which this human interaction is supported by manual or computerized tools varies. Both manual and computerized tools have their limitations.

In the *manual* games, the alternatives that can be jointly experimented are restricted by the limitations of the physical place and material, and also time, since the game runs have to be performed manually.

Using *computerized tools* in some parts of the simulation can cause limitations, since the dynamics of the game is restricted by the mathematical model and hidden into computer program, and thus cannot be "seen" and acted upon by the players.

Virtual reality gives new technological possibilities to overcome these limitations. Through the use of the latest achievements in multimedia, computer graphics and visual programming, a *visual interactive model* can be created for the group simulations and experimentations of both generic and specific enterprise systems. This is the development idea of the new Enterprise Simulation Laboratory at Helsinki University of Technology.

4 THE ENTERPRISE SIMULATION LABORATORY CONCEPT

The Enterprise Simulation Laboratory is being developed in a three year project 1997-2000 at Helsinki University of Technology, TAI Research Centre, as a collaborative effort of three laboratories: Industrial Economics, Industrial Psychology, and Telecommunication Software and Multimedia (TLM). The Laboratory aims to answer to the challenges of social simulation in both generic and enterprise specific models in a unique, multidisciplinary way: it supports the interactive human experimentation through the creative combination of existing *enterprise simulation games, dynamic mathematical models, and virtual reality*.

4.1 The virtual "enterprise space" for enterprise simulations

In the Enterprise Simulation Laboratory, the virtual reality for simulations will be created through the *virtual wall* concept¹ (Takala 1997):

On one wall of the laboratory, a huge three-dimensional picture of the simulated system is projected from a computer display. This picture can be flexibly modified applying computer graphics and e.g. video picture. The virtual wall gives almost unlimited possibilities to *visually model the enterprise "space"*, from the simple furnishing of the simulated room (e.g. applying animation) to the visual presentation of data, and even to the telepresence of the players in the virtual space (immersive virtual reality). Every player can simultaneously see and experience the wall, which enables a shared, social simulation experience.

During the simulation games, the virtual wall can support visual experimenting of enterprise processes in at least five different ways:

- 1) Conceptual simulation data can be projected to the wall, for every player to see: e.g. the layouts and process charts, performance measures, economic analyses of the processes; also outputs from mathematical simulations of the technical subsystems, if they are applied during the simulation game.
- 2) The physical simulation environment can be visualized in a two- or three-dimensional form: e.g. the future layout of the new company, the view of the workshop with its machines, the material flows and even the movements of virtual actors in the workshop. - The facilitator can change these images flexibly and quickly on the screen, even during the simulation.

¹The best known virtual space application, called CAVE, has been developed at University of Illinois at Chicago.

- 3) The players can interact directly with the virtual wall model, e.g. change the layout of the factory and the location of the machines in the workshop.
- 4) The players can immerse themselves into the virtual reality, e.g. into the planned future factory, and experience the space and the functioning of the factory from "within".
- 5) Even players at different geographical locations can participate in the same simulation, if the virtual wall picture is transmitted via interactive broadband telecommunication networks simultaneously to several locations. The players can interact applying CSCW technologies and interactive video, and even meet each other as virtual actors in the "enterprise space". The Enterprise Simulation Laboratory is thus not necessarily tied to one location, but can exist in a telematic network.

The two first points on the list above can be achieved with existing multimedia software, hardware, and simulation game methods, but the latter points require multidisciplinary research and development effort to create software and equipment for an appropriate user interface for the virtual "enterprise space".

4.2 Developing the Enterprise Simulation Laboratory

The Enterprise Simulation Laboratory's virtual "enterprise space" is a challenging multidisciplinary research agenda for the next three years. It is developed in a "concurrent engineering mode" with three cutting edge Finnish industrial companies representing machine industry, telecommunications and medical industry (Figure 2).

The needs of these pilot companies set high requirements for the Laboratory:

1) Pilot company A wants to develop a visual, generic simulation game to train the whole personnel in understanding the operations and strategies of a typical industrial company, and the connections between operational processes and economics.

2) Pilot company B is growing rapidly, and is moving to a new factory. It needs tailor-made technical and social simulation support to re-engineer its layout, production lines, material flows, and later its global logistic chains. The company is also in the process of implementing a new operations control system, and has to train its employees to the new processes.

3) Pilot company C is re-organizing its highly complex, knowledge intensive R&D process of medical drugs, and needs interactive social simulation games to be able to dramatically decrease the lead time of new product development.

The Enterprise Simulation Laboratory project proceeds in a prototyping manner with the three parallel pilots. For each pilot company, simulation model prototypes are developed and tested with company test groups. The evaluations of the prototypes' usability, learning effects, effects on innovations, as well as the technical requirements of software and graphics are important feedback for the development of the subsequent versions of the models and of the whole Enterprise Simulation Laboratory. (Figure 2)

Special emphasis has to be put from the start of the development project on the validity of the models and the learning effects of the simulations. The experiences that are created in the virtual enterprise space have to equal in relevant aspects the real enterprise processes, otherwise the players will learn the wrong lesson.

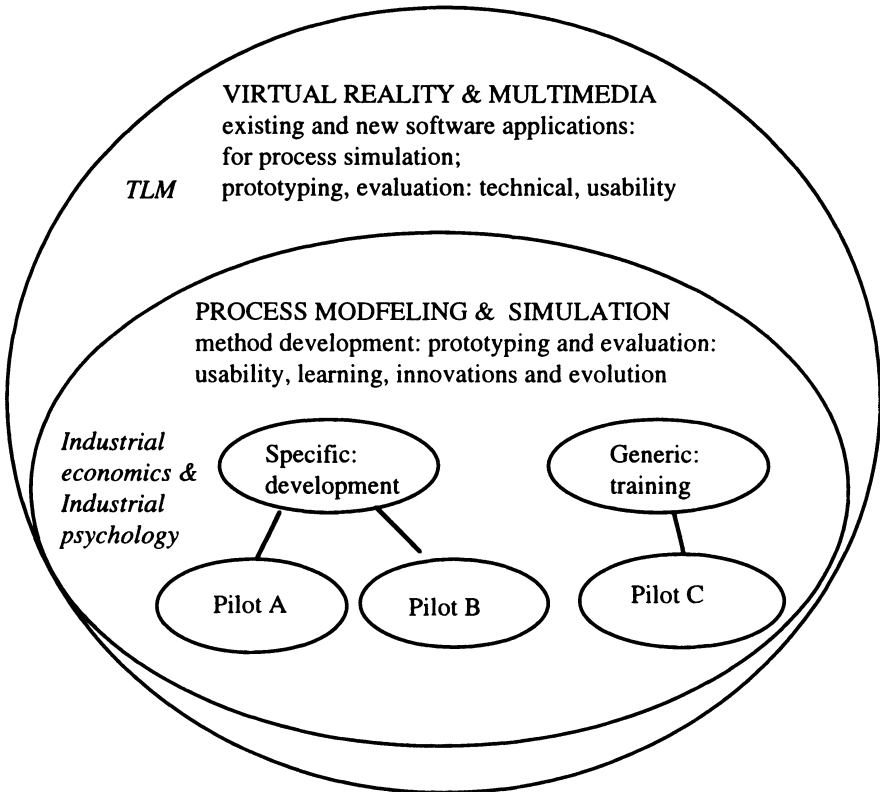


Figure 2. The development concept of the Enterprise Simulation Laboratory

4.3 The Enterprise Simulation Laboratory in future use

The Simulation Laboratory at Helsinki University of Technology is planned to continue its functioning after the three year development project, to serve three main user groups: the students, the industry practitioners and the researchers.

The Laboratory's technical construction, the virtual wall, can be applied to enable visualization and experimentation in the teaching of Industrial Management courses. E.g. computer simulation displays like the business game outputs after each game round can be projected on the virtual wall for the joint analysis and discussions by *student groups*. Cooperative work on the same model is possible on the virtual wall, and the combination of the virtual wall with telematics creates new possibilities also for students to engage in distant collaboration and learning. (cf Augustin, in this volume)

Practitioners from industry can firstly be invited for educational generic simulations to the Laboratory. But secondly, and more importantly, they can use the Laboratory as an "enterprise clinic" for their enterprise specific problem solving and process development tasks. Development groups can attend simulation games, which are tailored to the enterprises' needs and played in the virtual enterprise space of the Laboratory. This possibility is especially valuable in the simulation of an enterprise's future processes, where manual models would be too limited, rudimentary, and slow, and computerized mathematical models would inhibit the necessary social interaction for experimentation, synthesis and understanding. - The telepresence of players in the game makes it possible to simulate global processes of enterprises through the virtual meeting of players in the same simulation.

Multidisciplinary research teams will have excellent possibilities to study virtual reality and multimedia simulations of enterprise processes, as well as their user interfaces and learning effects, already in the prototyping phases of the project. Later, as an enterprise clinic, the Enterprise Simulation Laboratory will become a unique facility for research on new enterprise modeling and simulation techniques, and especially on the complex phenomenon of *organizational learning*. While using the Laboratory as a clinic for their internal development and problem solving tasks, the enterprises will provide rich empirical data for research on organizational decision making, innovation and experimental learning.

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Tailored simulation games for successful business process development

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Abstract

Enterprises suffer from a lack of strategy-based business process development methods in which, the dynamic knowledge creation as well as the implementation of a new process is present, already at the beginning of the project. The Softmatch Method is developed for this priviation. This article describes the principles of the Softmatch Method, and some empirical experiences. The Softmatch Method is a participative, systematic method, which is using customized simulation games as an integral part to achieve successful enterprise transformation in business process development. The Method involves different organization levels, and it is composed of different interactive elements, like teamwork, project management methods and simulation games. The participation of employees right from the beginning to design and implementation accomplishes high commitment throughout the whole transformation.

Keywords

Simulation games, business process development, dynamic knowledge creation, tacit knowledge, explicit knowledge

1 SOFTMATCH METHOD

Softmatch is a creative, participative and systematic method of discovering the change potential of business processes, of realizing the changes needed and of managing the changes. The method is aimed at the development of processes to support rapid changes in industrial and service companies, as well as in public organizations. It can be applied to radical and incremental change projects.

In the Softmatch Method the process development is based on business strategy and customer needs. The ideas and views of personnel are an integral part of the development work. During the development projects, new modes of operation are actively sought, and their functionality is tested in simulations. The concurrence of planning and implementation leads to rapid change.

Softmatch stimulates the whole organization's creativity, and manages the ideas systematically and efficiently towards a competitive business process innovation. The method combines simulation games, teamwork and project management in an iterative system of learning and knowledge creation (c.f. also Nonaka and Takeuchi, 1995). Through acting and experimenting in the cross-functional and cross-hierarchical simulation games, the method brings into the innovation process the tacit knowledge of the organization. Through teamwork and systematic project management, this tacit knowledge is converted into an explicit new process design. With the iteration rounds between simulations and project work, the innovation process proceeds in a prototyping manner, until a sufficient design is created (Figure 1). The method adjusts the range of change to the prevailing change capability of the company. Ideally, small change steps result in radical business process change, if the direction of change is set at the beginning of the project, and the continuity of change is accepted and managed as a learning process (Smeds, 1996).

The Softmatch Method uses both "soft" change management features and "hard" project management principles to engage the knowledge, skills and creativity of the organization for process development:

- a) "Soft" change management focuses on leadership, motivation, large-scale participation, communication, relationships within the organization, and ensuring the implementation of project results.
- b) "Hard" project management helps to define clear strategy-based change objectives, to schedule the change project, and to manage its resources.

The Softmatch Method creates a clear and logical development framework, that respects and makes use of the skills and creativity of all organization members. Analysis and synthesis iterate in a rapid cycle for development. It combines a joint, realistic understanding of the present situation, hard business objectives, and a creative approach to change. Simulation games, teamwork, project work and intensive communication are used as part of the method, which proceeds in

balance with the change capability of the personnel. Open communication is vital in change projects and without it, meaningful change cannot occur.

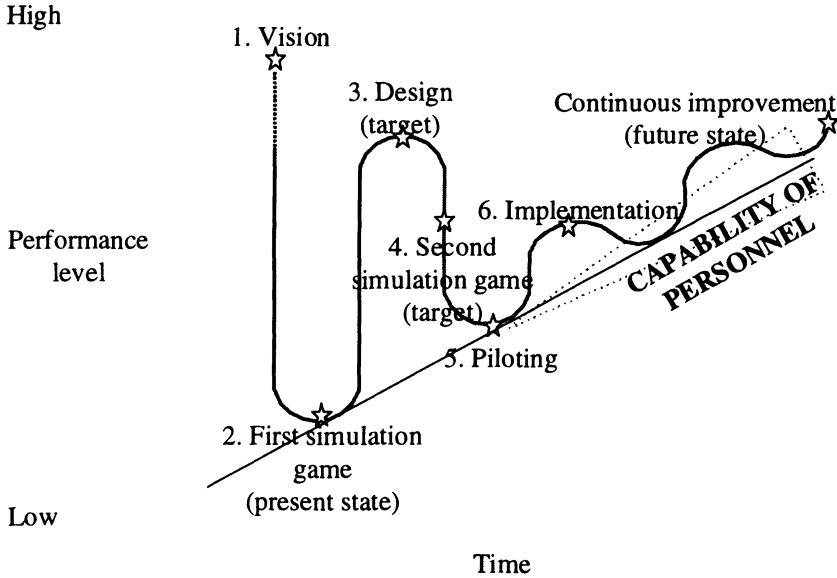


Figure 1. The Softmatch Method proceeds in a prototyping manner towards an accepted process design.

The Softmatch is built on the basic principle of participation. It starts the discussion about process-oriented development between management, employees and experts. The method also enhances personnel's own initiative in process development, which is a crucial asset in the turbulence of the present competitive environment. This choice has been made to ensure the implementation of the new process as rapidly and smoothly as possible. The simulation phases in the method create a shared understanding of the process, which increases the motivation of the employees and the change flexibility of the organization. Commitment to change arises from understanding the whole. Committed people build up a well-functioning process, which is then reflected in the subsequent corporate image in the customers' mind.

The six Softmatch phases (Figure 2) add up to a dynamic method, where "hard" project management and "soft" change management elements alternate and overlap. Analysis and synthesis are combined for rapid development: the first simulation game constitutes the analysis of the present state, while synthesis is created in the design phase and in the second game. In the discussions,

observations and solutions during the first game, synthesis for the new process are already being created.

Simulation gaming is systematic and visualized discussion about the activities and tasks in a chosen process, e.g. in the order-to-delivery process. To aid the simulation, the whole process is depicted on a big wall chart, and the meeting room is furnished as a “scale model” of the process.

The method allows the integration of human resources both vertically and horizontally during the change project, to achieve the best possible end result. Top management's role is vital in the first phase, when the target process and its development objectives are chosen, based on the strategy of the company. The piloting and implementation phases require top management support, commitment and participation as well. Throughout all the phases, the know-how of employees from different functions and hierarchical layers is crucial for successful change: the whole organization's resources have to be mobilized for change accomplishment.

At the beginning of the change project, individual change capabilities differ greatly: the common rhythm for change is missing. The change objective, the vision, can seem out of reach and detached from reality. The first simulation game harmonizes the change capabilities of the personnel and allows the change objectives in the latter phases of the project to become more demanding. Usually, the performance objectives are reached only after the implementation phase through continuous improvement.

In business process development projects, the first four phases of the method are realized in two to four months. The duration of the last two phases depends on the magnitude of the change and the size of the company. Smaller organizations can reap the benefits from change quickly, since all of personnel can participate in the design and experimentation of the new process in the simulation games. The implementation of the new process begins during the second simulation game and the need for change becomes obvious to everyone. In large global organizations, the implementation phase might take months, as it takes time to involve all the necessary personnel.

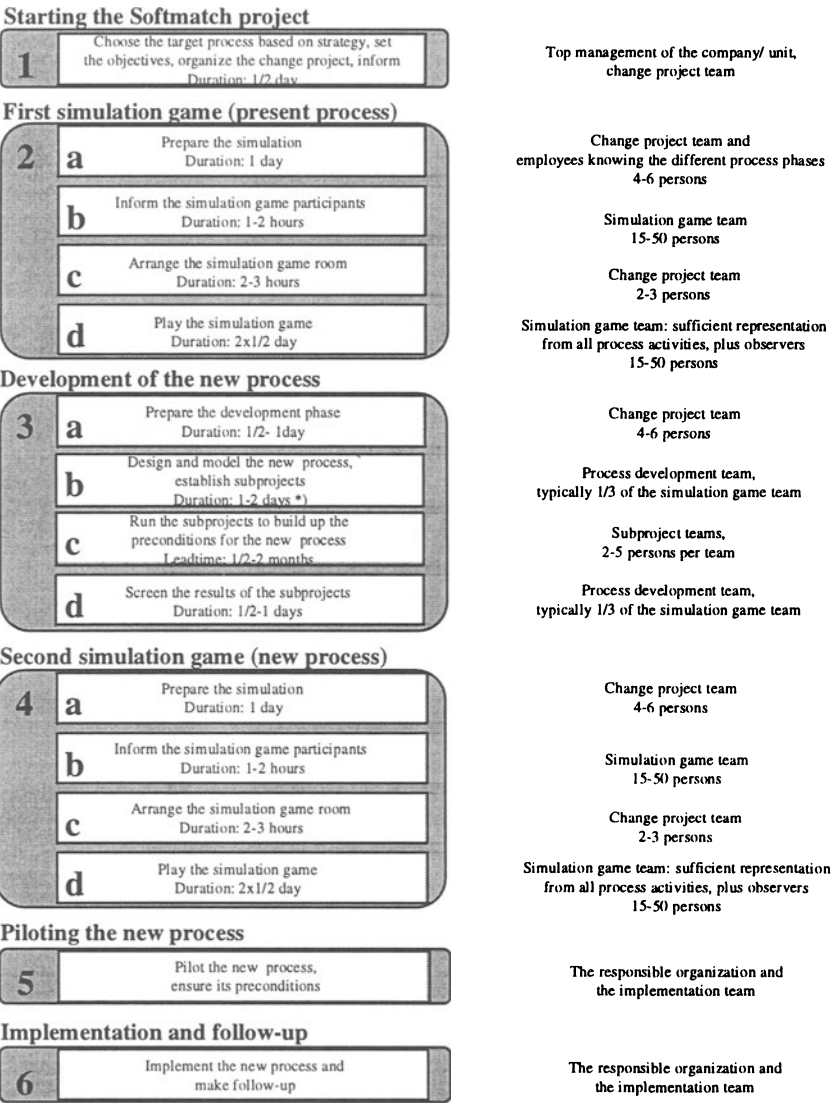


Figure 2. The phases and steps in the Softmatch Method.

2 EXPERIENCES IN FINNISH PILOT COMPANIES

2.1 Case 1: Developing an order-to-delivery process in a manufacturing company

Background

The company participating in the project is a Finnish company that develops, manufactures and markets products mainly for export. The annual turnover is approximately US\$250 million. The company operates internationally with around 1000 employees; its products are handled through both its own sales subsidiaries and through external channels. The entire business is divided into four strategic areas by business and product segment.

All efforts within the company to date had been concentrated on production. After years of slow development, business process reengineering became inevitable to improve competitiveness and cost efficiency. An overhaul of the operational management system was required and thus a careful study of the processes involved was necessary before defining the way forward.

The following objectives were set for change:

- create new process rules
- suppress work that does not provide added value
- reduce the number of activities in the process
- decrease process lead time
- improve delivery
- increase profitability

The condition of success was the wide participation by team members in the change being put into place; involvement would increase commitment and guarantee the implementation of the required changes. Other objectives included the promotion of autonomous initiatives for continuous development, as well as continuous change and learning with high flexibility. Simulation games were therefore chosen as a change management tool.

Essential points of the change project

The first simulation game. The participants in the *first simulation game* were staff carrying out the daily order-to-delivery process, co-workers in the support processes, the IT manager, as well as directors and managers in related operations within the company. A total of 50 employees attended the game; 18 actively played and the rest observed the simulation.

The simulation game was a systematic and visualized discussion about the activities and tasks in the order-to-delivery process. To aid the simulation, the whole process was depicted on a big wall chart and the meeting room was

organized to represent a "scale model" of the process. Computers and genuine order documents were used as simulation material.

The simulation was carried out by "reproducing" the handling of a customer order through the whole process, from initiation of the order to delivery. An in-house change champion prepared the simulation game and informed the organization about the change project and the simulation, while an external facilitator led the simulation and discussions.

One hundred and twenty-seven ideas, open questions and problems were identified during the simulation session. These were written on stickers and attached to the process description on the wall. The ideas were classified as follows:

- reorganization and shortening of the process
- clarification of the product range
- clarification of the process rules
- specification of the rolling forecast and capacity planning process
- modernization and intensification of the use of IT
- increase in the cooperation between production and sales

During the game decisions could be made. Seven different problems were addressed and resolved. Many decisions were made concerning the process control. Because decisions were being taken during the game, involving all the relevant parties, the interest level stayed high throughout and the actions decided upon during the simulation could be easily implemented afterwards.

The development of the new process and the second simulation game. Once the first simulation game had taken place, the next step was to develop the new process. The new process description was created by the *process development team*. The team had 24 members from different activities within the process who had taken part in the simulation game. Each function and hierarchical level was represented to ensure the best possible result. The team designed and modeled the new process.

Four parallel sub-projects were established to solve the prerequisites for the new process. The *sub-project teams* consisted of 4-6 people and were divided by subject:

- customer classification
- concepts and terminology in the process
- rules of operation
- relation between strategy and processes.

During the second simulation game, the new process and the new mode of operation were tested and improved upon with the complete simulation group.

Hypothetical customer orders were simulated; once again many ideas for improvement arose, were discussed, and subsequently became an important resource for the later phases of the change project.

Results

Results achieved during the simulation period. The two simulation games took place between August and October 1995. During this time the following results were achieved:

- a joint understanding of the past situation was reached
- the order-to-delivery process was defined and documented
- the business processes were planned and simplified prior to information system investments
- the role of the production process relative to the order-to-delivery process was clarified
- a common and unified terminology was developed that allowed clear, shared concepts
- an understanding of the importance of team work was achieved.

The business process design that was reached shortened the process from 30 to not more than ten steps per production line. The number of people involved in the process chain could be decreased from eight to three by combining tasks and reducing unnecessary steps by effective teamwork.

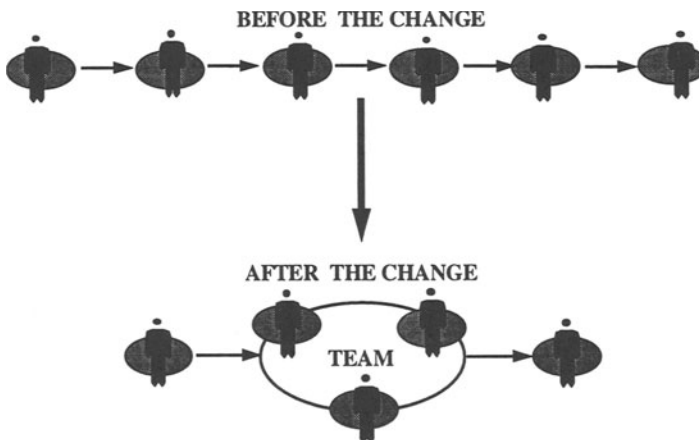


Figure 3. The possibility to use teamwork in the process was discovered during the simulation.

The participants reported that:

- The simulation games created a holistic understanding of the lead times and problems in the order-to-delivery process; for the first time the complex process was understood as a whole.
- All the people involved were, at last, present at the same time and were listened to. The managers with decision-making power were also present.
- It was important for everyone to see and understand the interconnections between activities and tasks. The simulation team can visualize the whole process whereas one person alone would be blind to many alternative solutions.
- Many new ideas were conceived.
- The simulation was a good training tool for smaller groups and newcomers.

Results achieved after the simulations. Six months after the second game, the simulations were a shared experience that were still referred to in the development process. The decisions made during the simulations were still valid. The simulation had provided a good basis and direction for future business process development and had helped to clarify the change objectives.

After the simulation games, two groups were established to foster teamwork within the company. Office workers, i.e. the people in the order handling, invoicing and dispatching departments, visited and worked in each other's jobs to learn the principles of teamwork. Information and training sessions were arranged and the payment system came under discussion.

The objectives of the change project were met within six months:

- The new process rules were for the most part implemented. The clarified process rules impacted directly on decreasing process lead time, eliminating work that was not providing added value, and improving delivery performance.
- Preparatory work for the new processes had already started with team training and related projects.
- The new process design and the clarified process rules had a powerful impact on the development of the new IT system, which proceeded effectively based on the process descriptions developed in the simulation games.

Finally, process reengineering and information system projects take time to put into place. Moreover, profitability can only be assessed after the implementation of radical change. At the date of publication, the final results of these two objectives had not been published.

2.2 Case 2: Developing an order-to-delivery process in small improvement steps

Background of the company and of the change project

The corporation involved in this project develops, manufactures and markets high quality hospital technology systems and services for export internationally. Its turnover is about FIM700 million and the company employs about 600 people. The corporation consists of four companies, which have a joint sales and distribution network.

The aim of the development project was to analyze the present state of the sales-to-delivery process and then improve it little by little.

The objectives of the Softmatch project and of the simulation games were to:

- gain an overall picture of the process to be developed
- improve the efficiency of the present process through improvements in
 - throughput time
 - delivery accuracy
 - quality of operations
 - turnover of capital
- support the design and experimentation of the new process
- increase the flexibility of the process and its ability to learn and change
- ensure the implementation of change through empowerment

Essential points of the change project

First simulation game. A total of 30 people participated in the first game, 17 as players and the rest as observers. The game followed case histories, supported by the process description on the wall. Two different case histories were used: a typical customer order, and an unusual order fraught with technical problems, material shortages and missing documents. During the game, ideas were developed on how the efficiency of the process could be improved, how unnecessary work and phases in the process could be dropped, and how problems could be solved.

The game produced 119 ideas, open questions and problems, out of which 100 concerned the sales-to-delivery process itself, while the remainder addressed support processes.

Based on the perceived ideas, open questions and problems, the development targets were grouped as follows:

- the process and its phases
- the information flow

- material flow and control, buffers, capacity, flexibility and accuracy of delivery
- information systems
- product changes and their management; disturbances
- training

Development of the new process and the second simulation game. The development and modeling of the new process was performed three weeks after the first simulation game. The two-day workshop was attended by about 15 people from the sales-to-delivery process and its support processes. In the workshop, the results of the first game were analyzed and the development objectives of the process were refined. These objectives were the starting point for designing the new process. After the new process description was finalized, the need for sub-projects was discussed. Resources were allocated to the sub-projects in order to create the preconditions for the new process, and time schedules were planned.

The themes of the sub-projects were:

- inventory and control of materials - fixing the buffer stocks required
- classification of orders and delivery times
- process measures
- managing delivery prohibitions
- elimination of unnecessary documents
- planning the second simulation game, taking into account the results from the sub-projects

The second simulation game was played according to the new process description, applying the new "rules of the game". The aims of the second game were to test the new process, its prerequisites and its rules, to train employees in the new mode of operation, and to stimulate development.

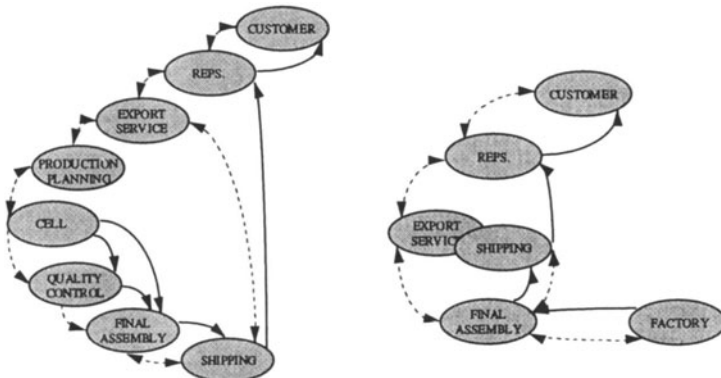


Figure 4. Process structure before and after the Softmatch project.

An important feature in the development project was that production was customer-driven only until final assembly; the job shop and the suppliers ran support processes that deliver the components to final assembly. The intermediary buffer inventory between final assembly and the job shop plays an essential role in the smooth functioning of the sales-to-delivery process. When this buffer works well, unnecessary inquiries can be avoided, delivery accuracy remains good and flexibility is ensured.

While the new structure of the process did not change much, the prerequisites for its functioning changed considerably.

Piloting the new process. The pilot phase was planned with a restricted amount of sales areas and products in order for it to be manageable. If the pilot was successful, the new mode of operation would then be spread to the wider process.

Results

The project resulted in many small improvements. People implemented improvements both during the pilot phase and after. The many inefficiencies of the process were eliminated and unnecessary activities completely dropped.

The rules of cooperation between sales and production were clarified and recognized. The same issues were understood differently in different parts of the process. The clarification of concepts facilitated inter-functional cooperation and thus increased flexibility. Sales and production now communicate and genuinely cooperate.

As a result of the project, customers could be given more accurate delivery dates and the rules for handling orders for project deliveries and quick deliveries could be explicated. The principles underlying production control were re-assessed and the levels of buffer inventories were adjusted to correspond to demand.

Production flexibility improved and delivery accuracy has remained high.

3 CONCLUSIONS

Experience with nine pilot companies as external process development facilitator has demonstrated that it is essential to combine the development work into a systematic framework, which we call Softmatch. The Softmatch phases add up to a dynamic method, where “hard” project management and “soft” change management elements alternate and overlap, and where different development methods and tools are combined and used during a change project.

In the Softmatch framework (see Figure 2) special emphasis is put:

1. on the preparatory strategic analysis of the change need and the goals of the project. The change has to be organized into a formal change project of the company.
2. on carefully informing the whole organization about the change and the simulation games.
3. on the right composition of the different teams involved during the whole change project (see Figure 2 right hand column)
4. on the importance of the development phase between the simulation games, and the role of the sub-project teams to build the preconditions for the new process.
5. on flexibility in using the framework: the day-to-day operations, other ongoing change projects and learning during the change project itself require iterations and adjustments to the method. In fact, the change objectives are often modified during the project.
6. on the fact that the successful change project requires that first an internal change champion and then the whole organization take over the method and drive the change towards implementation.

The Softmatch Method helps the organization to test the new mode of operation and its functionality before implementation and it encourages employee initiative and rapid process-oriented decision making. The method also increases the employees' shared understanding and customer focus as well as improves relationships and collaboration between people and functions.

In the Softmatch Method, the present state of the process is modeled rapidly and cost-efficiently. Heavy analyses are avoided; rather, energy is saved for the discovery of new solutions and establishing the change. The systematic, simultaneous and visual connection between all individuals concerned results in joint understanding of the present situation and its change needs, acceptance of the need for change and the means to achieve it and rapid and smooth implementation of the new mode of operation.

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5 BIOGRAPHY

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Participative Simulation Game as Facilitator of Organizational Development Process - Two case studies

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Abstract

The main use of simulation games is developing business processes i.e. analyzing and testing processes and training of employees. It can be used as a tool in different phases of the organizational change process; in analysis, planning, testing, and implementation phase. According to the research results the participative simulation game method has proven to be an effective facilitator of the organizational change process.

The paper is based on a descriptions of two case-studies. *Firstly* the aim of this presentation is *to describe the participative development processes*, where simulation games were used as facilitators in the analysis phase. *Secondly* the paper will *discuss the role of the simulation game* and the other factors in terms of *success of the implementation phase*.

Keywords

Simulation game method, case study, food industry, printing house.

1 INTRODUCTION

A simulation game is an interactive and participative development method which can be used in various phases of the development process (Haho & Smeds 1997, Hakamäki & Forssén-Nyberg 1996). It helps companies identify technical and non-technical problems within the organization and current business processes. It can be used to simulate information and material flows within the processes as well as aspects of internal and external communication. The simulation game can be used to create the ideal process and test and evaluate needed changes in the business processes before implementation. It is a good training method as well. The simulation game must always be tailored to the process and environment where it will be used as a development method.

According to the research results the participative simulation game method has proven to be an effective facilitator of the organizational change process (Haho & Smeds 1996, Forssén-Nyberg & Hakamäki 1997, Ruohomäki 1994). For instance a common understanding of the process increases employee motivation and commitment to changes.

2 THE FOOD INDUSTRY CASE

The case study concerned a food industry company and concentrated on development of the R&D process by using a simulation game.

The R&D process goes through several business functions: from marketing to the R&D department forward to production and finally to delivery. Projects are carried out in two semi-annual cycles: the first launch is in spring, the second in autumn. Normally R&D projects take half a year, though some may take longer. Several R&D projects are active simultaneously.

The R&D process can be simplified as follows: The product manager from a marketing department, who works as an R&D project manager, is responsible for project planning, advertising planning and packing material designing. She/he manages the whole project and makes decisions about the final product. Meanwhile the R&D department is testing and choosing raw materials. R&D assistants repair different kinds of samples according to the instructions received from a product manager. This testing phase of the process is called piloting.

Production tests follow piloting. Production can be divided into two phases: a trial trip and production. The aim of the trial trip is to find the right raw material combination and production run parameters. Production starts running when everything is tested and fixed.

2.1. Objectives

The development project started in autumn 1996. The aim of the project was to model the R&D process and to develop tools or methods for project management (e.g. scheduling). Simulation games were used in both phases: primarily to analyze the present state "as is" and to develop the ideal process as well.

More detailed goals were set for both simulation games. The objectives of the first were:

- to point out the problems and development needs of the present R&D-process
- to increase the understanding and knowledge of personnel about the whole process
- to increase cooperation between employees

The objectives of the second simulation game were:

- to clarify the material and information flows in the process
- to model the "ideal" R&D-process
- to derive concrete improvement ideas for the development work

2.2. Simulation game project

The simulation games were planned by the planning team. The planning team consisted of a production manager, product manager, R&D researcher, administrative manager (project manager) and two external facilitators (two researchers). Even though the researchers were principally responsible for the project, the company named one person, the project manager, to take responsibility for their side. (Figure 1)

Altogether the planning team had meetings twice before the first game and four times before the second. The aim of the planning team was to design the form of the games, to describe the work process, prepare and design all visual material, send invitations and prepare the game site. The researchers also collected data and information about the process by interviewing employees.

There were about 40 people participating in each simulation game. In addition there were researchers acting as leader and the secretary. Representatives of material suppliers and advertising offices as well as customer and consumer delegates were also invited.

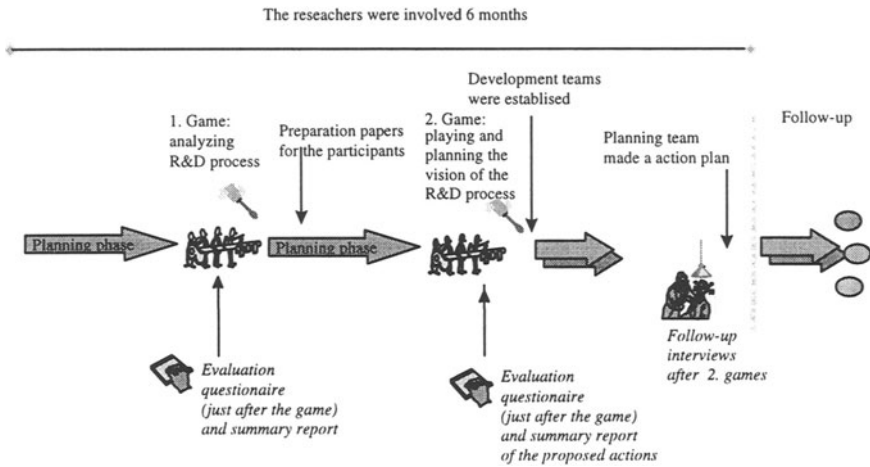


Figure 1. The development project of R&D process.

The first game

The first game round was used for analyzing the present state of the R&D process. The process was visualized by a large process flowchart, which was placed on the wall. The day was divided into two parts: two game tours and one group task. Each player explained to the others his/her tasks in the process by answering the following questions:

- what he/she is doing
- what is produced and for whom
- what tools, material and information are needed and how to acquire them
- what problems exist with the present way of working

The players also showed their work area in the flowchart.

The second game round tour was based on analyzing the present situation through an example project selected from the recent past. The purpose was to simulate a real project and the typical problems that occurred. Before the game, all documentation related to the case example was collected.

A group work session was held after game. The objective of group work was to point out the five largest problems in the process and if possible, provide some improvement ideas.

The main development targets according to the results of the simulation games were: the beginning of the project (such as the content of the project plan, or who should be involved in the first project meeting), the planning of investments, the project management and the evaluation of projects.

Altogether 38 employees filled out the evaluation questionnaire. According to the questionnaire, participants were satisfied with the days (Table 1): the average of the grade for all answers was 4.0 (on a scale of 1-5, where 1=very much disagree and 5=very much agree). The most indispensable outcome according to the written answers was that the game increased the common understanding and knowledge of the process in general.

Table 1. The quantitative answers of the evaluation questionnaire (on a scale of 1-5, where 1=very much disagree and 5=very much agree).

<i>Evaluated statements on the simulation games (n=38)</i>	<i>Grades</i>
<i>The game would also be useful for other employees in the company</i>	<i>4.4</i>
<i>Participants have much opportunity to comment</i>	<i>4.2</i>
<i>The game pointed out well the development needs in work processes</i>	<i>4.1</i>
<i>The game increased knowledge about work processes</i>	<i>4.1</i>
<i>It was useful for employees to participate</i>	<i>4.4</i>
<i>The game bring up ideas of action plans</i>	<i>3.4</i>

The second game

The second game was used as a tool for participative process redesign such as creating a mutual vision of the ideal process. The focus was on information and material flows. A preparation paper was sent to all participants. There were questions about "as is" information and material flows as well as the need to change the current situation.

A large project schedule was placed on the wall. An ideal project schedule was drawn up based on the process model.

The players represented different phases of the R&D process. Each player explained the material and information needs from their point of view. Information or material needs were illustrated with a piece of paper attached to the corresponding place on the project schedule. If there was some kind of problem in information or material flows, it was marked with a red piece of paper. After every phase there was discussion about the problems, which the observers also took in.

The key finding was that it was impossible to build an ideal project model under current circumstances. To improve scheduling considerably would necessitate major changes in the operating model. Currently many scheduling objectives are contradictory, all necessary information is not available when needed and there is not enough time to take preparatory steps and actions for a new project.

At the end of the day, every participant filled out an evaluation questionnaire. Results were summarized and reported back to the participants by the researchers. Altogether 31 employees filled out the evaluation questionnaire. According to the questionnaire, participants were satisfied with the days (Table 2): the average of the grade for all answers was 4.1 (on a scale of 1-5, where 1=very much disagree and 5=very much agree).

Table 2. The quantitative answers of the evaluation questionnaire (on a scale of 1-5, where 1=very much disagree and 5=very much agree).

<i>Evaluated statements on the simulation games (n= 31)</i>	<i>Grades</i>
<i>The game would also be useful for other employees in the company</i>	<i>4.3</i>
<i>Participants have much opportunity to comment</i>	<i>4.3</i>
<i>The game bring up ideas about action plans</i>	<i>3.9</i>
<i>The game illustrated the ideal project</i>	<i>3.8</i>
<i>It was useful for employees to participate</i>	<i>4.5</i>
<i>The game illustrated material and information flows</i>	<i>4.1</i>

The development teams were established after the games. The objective was to design an ideal process model based on the work carried out in the second phase and propose how to solve the problems marked with a red paper on the process schedule.

After the development teams finished their tasks, the planning group of the project made an action plan for the near future. The plan was presented to the development manager, the owner of the R&D process.

The researcher evaluated the development project by interviewing some of the participants one month after the second game. According to the interviews there were a lot of expectations about development action. Some people (workers, foremen) were a little disappointed not much has happened from their point of view. People expected more information on plans and decisions. On the other hand, managers told that some big changes in project management had appeared. Nevertheless, some improvements were implemented immediately following the simulations games. The information flow between the piloting phase and production was improved. Many people said that it was much easier to communicate and give information to others after the games. More people were invited to project meetings to ensure communication on project status as well. The discussion on future projects began also much earlier than before. The quality

system was improved. The new project schedule was used even though it was not suited to every project because of different project types.

All the people interviewed thought that the simulation game as a development method was a very good and interesting way to go through work processes and bring up related issues.

3. THE PRINTING HOUSE CASE

The case study was done in one part of a large printing house. This part was specialized in serving customers who needed leaflets, business cards or transparencies printed quickly. Around 25 were employed at this “express” press in 1995.

3.1. Objectives

The first aim of the project was to train employees to understand the whole order-delivery process. The second was to improve customer service and “people” skills with the customers. The idea for this project originated with the training manager of the company.

3.2. Simulation game project

The planning team was established at the beginning of the project. The team included representatives from every work phase of the “express” press (workers and managers), as well as a researcher as a facilitator, totaling eight people. The planning team chose three products for which the order-delivery processes were simulated and drew up the first version of the process flow charts.

The game was designed in a participative way (see: Forssén-Nyberg & Hakamäki 1997). The process flowcharts were drawn in more detail and the typical problems of the work process were defined together with employees. In addition to collecting data with the employees the researcher met customers of the three products. The preparation carried out in Spring 1995 was conducted by a researcher. (Figure 2)

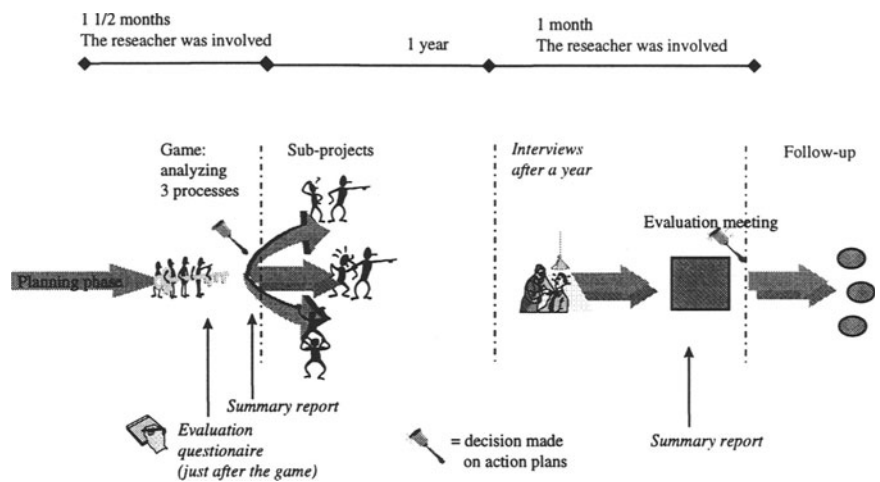


Figure 2 . The process of the printing house case

The game itself took one day (eight hours). It included three separate simulation games and a summary discussion. Thirty-two employees of the company participated in the simulation game as well as two researchers, the facilitator of the game and the secretary. The customers of the three products were also invited to the simulation game to each play the role of customer.

Table 3. Example action plans.

Action	Responsibility	Dead-line
Customer training	The marketing manager of the press	End of summer
Send renewed mailing list to press where the mailing process could be made easier	Customer	Right away
Test and choose new raw materials (paper) to achieve a better printing result	The customer and the press	To begin right away

The secretary collected the development needs suggested by players or observers during the simulation games. After the games we discussed the development needs and how to proceed with them. From the summary discussion we were able to outline an action plan (what will be done, by whom, and when) (Table 3).

At the end of the game, every participant filled in the evaluation questionnaire. The researcher took the minutes of the simulation game day, mailed to all participants after the game.

Both quantitative and qualitative methods were used to collect data on participants experiences. Altogether 28 employees filled in the evaluation on a simulation game, which included 15 questions. According to the questionnaire, participants were content for the day (average grade of all answers was 4.2 on a scale of 1-5, where 1=very much disagree and 5=very much agree). The game increased the comprehension and knowledge of personnel about three work processes from start to finish (grade 4.4) (Table 4), which the written statements support. They felt that it was useful for them (4.4) and would be useful for others (4.5) as well. According to the responses the most telling outcome was the opportunity to get to know and talk to people from other departments. The lowest scores were given to information about production costs (3.8)

Table 4. The quantitative answers of the evaluation questionnaire (on a scale of 1-5, where 1=very much disagree and 5=very much agree).

<i>Statements evaluated for the simulation games (n= 28)</i>	<i>Grade</i>
<i>The game would be useful for other employees of the company</i>	<i>4.5</i>
<i>Participants have good opportunity to comment</i>	<i>4.1</i>
<i>The game pointed out well the cause-effect relationships in work processes</i>	<i>4.3</i>
<i>The game increased knowledge of three work processes</i>	<i>4.4</i>
<i>It was useful for employees to participate</i>	<i>4.4</i>
<i>The game provided information about production costs</i>	<i>3.8</i>

The following spring (May-June 1996) the researcher conducted follow-up interviews. The aim of the interview was to evaluate the results of the simulation game project and the impetus for this follow-up came from the researcher. She interviewed two customers and 15 employees who participated in the game the previous year. The interview included questions about action plans, whether those actions had taken place and if not, what were the reasons.

Many interviewees indicated that it is essential to write down the action plans right after the game and then do a follow-up, otherwise things do not happen: the follow-up is imperative in terms of achieving results. The follow-up should thus be a continuous process such as twice a year and not just once was this case. Employees of the press as well as customers said that working together became easier after the game.

The researcher presented a summary of the interviews at the evaluation meeting to which all participants of the simulation game were invited. According to the follow-up interview nine out of thirteen actions were completed. As a result of the evaluation meeting some new action plans were drawn up; one customer representative, for instance would visit the printing house to see the process, test and change printing inks for one product to make production more runnable and decrease the passing through time. The follow-up of these actions is responsibility of the press as the researcher was no longer involved.

4. CONCLUSIONS

The results from these case studies support the results of earlier studies: the simulation game is an effective participative method of learning for example increasing common understanding of the work process. The simulation game is a very good tool for training people to see both their role in the work process and the process as a whole, to collect vital information from employees about problems and development needs and to commit people into the change. Still, it is just one tool and the real development work, "hard work" starts after the game as was seen in both cases.

Secondly, the follow-up is very important for the success of the project. Decisions are made easily at meetings, but too often implementation fails. A systematic follow-up is a driving force of implementation.

Thirdly the facilitator of the project can either be an outsider or a organization's internal change agent. According to the interviewees of the press, little would have happened without a facilitator from outside, especially as it was the first time simulation games were used in the company. The role of the outsider was essential in the simulation game, where she was a facilitator, as well as in the follow-up phase.

Fourthly the work of the planning team was very successful. The roles on the team were clear: company representatives offered their knowledge of the substance and the researchers their knowledge of the development method. With researchers and representatives of company planning the game together, these two areas of knowledge were integrated efficiently.

Finally, according to the results of the food industry case it would be possible to use a simulation game method in different phases of a development process and for different purposes. Using the simulation game several times encourages people to

participate in development during the whole project. After the first game the method becomes familiar, so it is much easier to participate in subsequent games.

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7 BIOGRAPHY

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How to disseminate knowledge and skills from using a tailored simulation game

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Abstract

Today's organisations live in the middle of a rapid change. Therefore, it is essential to create and spread new methods and skills in order to support self-directed learning and development activities in work organisations. This article focuses on spreading of methodological competencies of using a tailored, social simulation game called the Work Flow Game, which has proved very effective for business process development. Experiences of a learning environment based on a cluster of organisations are presented. The aim of the cluster was to develop and test the Work Flow Game, and to disseminate skills and knowledge from using simulation games to the participating pilot organisations so that the method could be used independently. In addition, another promising training model is presented and some preliminary results are discussed.

Keywords

Dissemination of development methods, Work Flow Game, organisation cluster

1 INTRODUCTION

In today's continuously changing business environment, it is not enough to master the product design, technology, marketing, production and delivery processes as such. Work processes and the ways of action are being reshaped, and both individuals, teams and the organisations as a whole face new learning challenges. In order to stay competitive, organisations need to develop new competencies in terms of self-directed learning and organisation development. Several case-based experiences show that a process development method called the simulation game* is a very useful development method for both production systems and administrative application areas (e.g. Forssén-Nyberg & Hakamäki 1996; Haho, in this volume; Smeds 1996; Piispanen & al. 1996, Ruohomäki 1995). In the Work Flow Game, three key factors of organisation development are combined: improving (or re-engineering) work processes, experiential learning and participative design.

To achieve long-term organisational change effects, there is an evident need to apply methods like the Work Flow Game to various work organisations and processes. Yet, the use of the Work Flow Game has been typically based on individual development projects, in which an outside consultant or researcher has acted as a change agent and the methodological expert. As a consequence, spreading of methodological competencies and extensive utilisation of the Work Flow Game have been slow and the development work has usually focused only on certain restricted areas within the organisation.

2 HOW TO SOLVE THE DISSEMINATION PROBLEM?

The situation described above presents the traditional problem of disseminating knowledge, methods, best practices, and successful experiences beyond the pilot projects. Training, case examples, site visits and publications present ways of solving this problem, but results, however, have often been disappointing. (Gustavsen 1987.) The dissemination problem can be discussed in relation to the volume of dissemination and the effectiveness of the interventions (Figure 1). Information campaigns, publications and standard training reach a great number of

* The simulation game focused on this article is called the "Work Flow Game" (Piispanen & al. 1996, Ruohomäki 1995). This simulation game type has also been called a "participative simulation game" (Forssén-Nyberg & Hakamäki 1996), "tailored simulation game" (Smeds 1996), and "social simulation game" (Smeds, in this volume). There are some methodological differences between these simulation game variations, but the basic innovation, the use of tailored, social simulation games for participative development of work processes, is similar in all variations.

organisations and their people, but that does not guarantee a real change process, i.e. implementing new ways of action, and sharing knowledge and methods in a wider organisational context. Individual development projects, which are based on wide participation of different professional groups, are likely to give better results, but such projects require a lot of time, financial and human and resources. (Saarela 1991.)

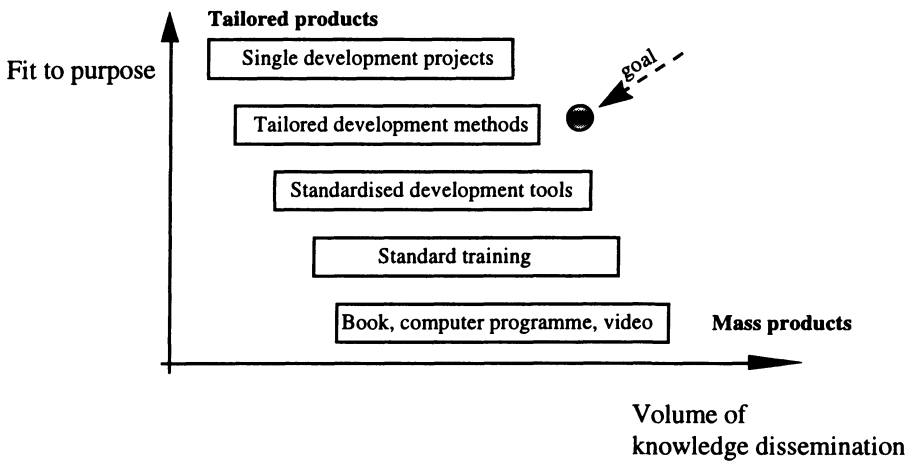


Figure 1. Tailored development methods can be disseminated and they fit the purpose.

There is a challenge to create tailored development procedures and methods, so that several organisations can be involved in development projects at the same time by tailoring the procedures and methods for their individual needs and contexts. One of the main characteristics of the Work Flow Game is that it is always tailored to the specific needs of an organisation. This can be regarded as being its methodological strength and weakness at the same time. Process development requires tailor-made, context-bound development methods, but disseminating and implementing of a tailored knowledge product is much more complicated than a standard development tool.

Perhaps the best known example of trying to solve the dissemination problem is the Swedish LOM-programme (LOM is an abbreviation of the Swedish terms for Leadership, Organisation and Codetermination), which was based on creating organisation clusters and networks, and using democratic dialogue and dialogue-conferences as a means of getting different organisations and interest groups working together (Engelstad & Gustavsen 1993). The literature concerning learning organisations also presents possible solutions to this problem, such as benchmarking, cross-learning best practices, and knowledge sharing through common experience databases. (e.g. Marquardt 1996.)

In the LOM-programme, networks were based on **organisation clusters**. In the Finnish literature, a concept of "Cluster development" has been used to describe development projects, in which representatives of a few organisations work together in terms of organisation development. The aim of such clusters is usually learning from others, working on common objectives or themes, or developing and learning new working models or methods that are interesting for all participants. Different types of cluster development can be identified: thematic, regional, field of business/way of action based, method based and experience sharing. (Laitinen & al. 1996; Pankakoski 1996.) This article presents a cluster that was characterised by combining training and organisation development into meaningful learning at work, testing and disseminating a new process development method, and having a few very different organisations working together.

3 ORGANISATION CLUSTER AS THE LEARNING ENVIRONMENT OF THE SIMULATION GAME

The cluster project presented in this article was carried out as a part of the Finnish National Productivity Programme (1993-). In order to test, study, further develop and disseminate the Work Flow Game method in a few different organisations at the same time, a method-based cluster was established in early 1995. Spreading of knowledge was defined at two levels: 1) developing work processes by using the Work Flow Game in the pilot organisations and 2) using the new methodological competencies independently of the original projects by the pilot organisations. Achieving results at level two was seen especially challenging. The development projects and learning the method were supported by common training day in each main phase of the development process. The role of the training was to support the execution of the pilot projects and to give a theoretical background for understanding the logic and different possibilities of using the Work Flow Game method.

There were five organisations in the cluster representing four different lines of business: a vocational training organisation, a ministry, an industrial company (chemical industry) and two insurance companies. The insurance companies belonged to the same company group, so they were not competitors and could thus openly work together. In order to promote the main principles of the game method, participative development and learning together, the learning unit of each participating organisation was a planning group. The planning groups were based on wide representation of different professional groups and hierarchical levels of each organisation. Each was to take part in the training days and then use the game method in their development projects with the assistance of the researchers.

The planning of the simulation game day was instructed in common training days, which were built upon the phases of the game method (Figure 2). In the cluster model, the training days were always followed by fieldwork in participating organisations so that the theory could be put into practice immediately. In each

training day, there were learning tasks that were started together and then given as homework for the pilot organisations to be completed during the fieldwork period. The idea of the learning tasks was to support and direct the development projects.

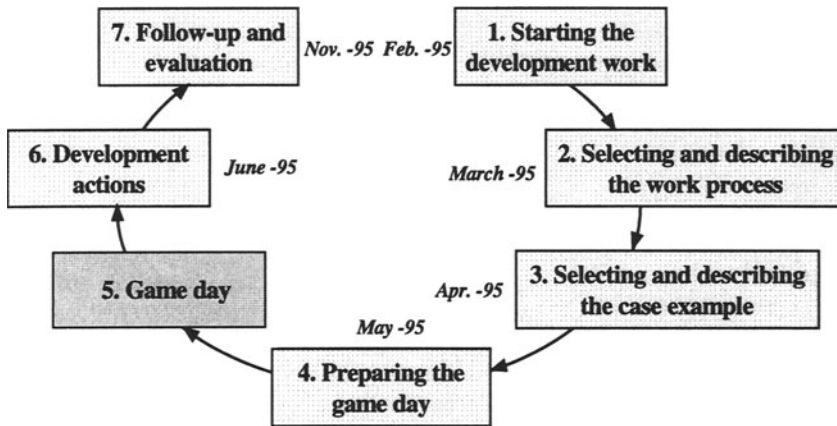


Figure 2. The cluster training proceeded according to the phases of the Work Flow Game method.

4 EVALUATION OF THE CLUSTER

During the cluster project, the researchers conducted action research about learning and organisational effects of the pilot projects, the experiences of simulation game participants, disseminating of methodological competencies and the cluster model as a learning environment. The objectives of the study concerning the cluster model and dissemination were firstly to evaluate the cluster a) as a means of combining organisation development and training b) as a way of developing different organisation together and c) as an environment for developing and testing the simulation game method. The second objective was to follow-up the self-directed use of the method after the pilot projects were finished. The research was mainly a qualitative, action research oriented case study. It was based on describing, understanding and evaluating the cluster model. The most important research methods were semi-structured interviews and questionnaires. The emphasis was on process evaluation in order to direct and develop action already during the study. (Pankakoski 1996.) The main results are summed up in the following chapters.

4.1 Pilot projects gained results

According to the representatives of the pilot organisations, training and organisation development were well combined. The training days structured the planning process of the simulation games, provided new information, presented the pilots with opportunities to share experiences, and offered a peaceful place and time for the planning groups to work together. The learning tasks for the fieldwork periods scheduled the planning process and supported learning of the game method. From the researchers' point of view, the organisation cluster offered a valuable environment for testing and developing the method, which showed that the game method is applicable to developing various kinds of work processes both in the public and the private sector.

Regardless of the outcome of the development actions, one should not forget that completing a development project is always an achievement as such. The reason for success in this case was a systematic approach to carry out the projects step by step. The pilot projects had a clear goal and timetable. The common training days were in the supporting role, whereas the most important work was done in the field together with the researchers. This is perhaps one of the main differences compared to some other types of clusters, where sharing experiences, discussion and co-operation play the main role, but the development actions outside the cluster meetings are solely the responsibility of the participants. (Juuti & Varjo-ranta 1993, Lahtonen 1996, Naschold 1992). On the other hand, in this cluster, the participating groups were not as self-directed as they could have been without outside resources.

4.2 Different types of organisations: pros and cons

The main advantages of having different organisations working together concerned methodological cross-learning and sharing experiences. On one hand, different lines of business made the cluster interesting, but on the other hand it also made learning from others more difficult. Even so, having different types of organisations in the cluster was a necessity in order to reach the method development goal. A few participants felt that belonging to the cluster increased the credibility and legitimacy of the project in their own organisations. Moreover, the cluster meant a stimulating competitive position for some participants in terms of comparing one's own performance to others. Lahtonen (1996) brings up similar observations based on her study about democratic dialogue and networking in Finnish metal industry. Working together had made it easier to get started with the development projects, encouraged the participating organisations in their efforts, and created a positive social competition within the cluster.

Other shortcomings of the cluster model concerned the differences of the pilot organisations in terms of facilities for carrying out a development project as well as a lack of interaction between the pilot organisations. During the training days

there was no time to have, for instance, mixed groups or other special inter-organisational tasks. Interaction could have been increased by making more visits to other organisations, especially by participating more in the game events of others.

Only two pilot organisations had co-operation outside the cluster events. The preconditions for true co-operation include a common goal, problem or objective. The starting shot for co-operation may be a problem that is bigger than any organisation can solve alone. (Gray 1985.) In this cluster, two pilots had a common theme, labour market training, which is an excellent example of a significant social issue that requires the input of several organisations and stakeholders.

4.3 Self-directed use of the game method got started

The cluster was successful in spreading of methodological know-how. Firstly, all the planning groups were able to carry out one or two process development projects during the cluster by using the Work Flow Game method. Secondly, and more importantly from the viewpoint of this article, during the one year follow-up period, three organisations used the game method independently and all the pilot organisations thought they had acquired a good level of competence in terms of applying the Work Flow Game.

The new game leaders had managed well in terms of facilitating the game events. In the new simulation game projects, the method had been applied to specific organisational needs and also combined to other earlier used development methods. Yet, the main characteristics of the method were still clearly identified in the new game variations. These results show the advantages of tailored development methods.

When evaluating the dissemination or diffusion implications, attention should be paid both to the transfer of learning and continuity of actions (Baldwin & Ford 1988). We can talk about transfer of learning concerning the three organisations that carried out new games without outside resources. A more far-reaching follow-up period is needed to assess the continuity of their efforts. Based on the latest interviews it could be assumed that these organisations have serious plans and good preconditions to continue utilising the game method in their future work process development projects.

Based on this case study, some critical factors for starting a self-directed use of the game method can be listed: responsible persons who have time and competence for carrying out new development projects, a conscious decision to learn and use the method as a development tool, previous experience in organisation development or using experiential learning methods and, a real need to apply the method in the work community. In future clusters, more attention should be paid to the composition of planning groups. In each group there should be persons who are responsible for organisational development tasks to ensure the dissemination of methodological knowledge. In method based clusters it is

similarly important that all participants aim at learning the method instead of developing only a certain area. On the other hand, even a method-based cluster consists of both the method and the chosen development object. Therefore, there should also be persons who know the substance of the development area sufficiently.

The transfer of training is affected by several factors. Robinson & Robinson (1989) present a formula for the impact of training: Learning Experience x Work Environment = Business Results. Learning by itself will be insufficient to produce on-the-job results, if the work environment does not encourage the use of skills learnt in the training. According to the experiences of this case, two new factors could be added to the formula: the object of learning (e.g. a development method) and the ability and motivation of the participants to apply things they have learnt. The properties of the development method present the critical factor as far as disseminating knowledge and skills from organisation development are concerned. Even though tailoring the method has been emphasised, the method should be well documented and to some extent formalised so that it can be communicated to new users. Yet, the method is not to blame if potential users do not have the need, ability or organisational support for applying it.

5 SIMNET TRAINING PROGRAMME FOR DISSEMINATING THE WORK FLOW GAME

Five organisations participated in the simulation game cluster. In order to get much more organisations involved, a new training programme called SIMNET was started in 1996 (Teikari et al. 1995, 122). The aim of the programme is to train dozens of new simulation game experts, who are able to apply the method in their own process development projects. The programme has been designed according to the model described in this article: training days, learning tasks and field work are linked together based on the phases of the game method to form an action learning type of project (cf. Revans 1982). The main difference compared to the cluster model is that only the change agent, i.e. the game facilitator, participates in the training day instead of the whole planning group. The game facilitators are responsible for carrying out their development processes independently in their home organisations without outside change agents.

During 1996 and 1997 two SIMNET training programmes have been carried out. eleven new game facilitators from ten different organisations were trained during the first programme. The results are very promising: all participants succeeded in carrying out independently their process development projects by using the Work Flow Game. Five of them have already applied the game method to new change processes. Ten new game facilitators from eight different organisations were trained in the second programme. The first results were very good again: eight participants completed their projects during the programme, and three of them started a new development project right after the first simulation games.

6 CONCLUSIONS

The cluster and the first two rounds of SIMNET prove that the method can be disseminated and used independently if instructed and supported systematically. This is encouraging in terms of national productivity efforts, for these kind of programmes reach several organisations at the same time and can be regarded as an efficient way of using development resources. Moreover, this approach is also relevant in terms of co-operation between universities and work organisations: researchers can develop and disseminate the latest methodological innovations in the area of organisation development and at the same time facilitate work communities to get more independent in their development efforts. There is a follow-up study going on about the SIMNET programme, which makes it possible to compare the effects of different knowledge sharing models of the Work Flow Game and organisational innovations in general.

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Handling the unexpected - a case study of computer support for workplace learning in chemical industry

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Abstract

In general, process control automation affects operator work knowledge and can potentially hamper development of the operators ability to handle production disturbances. In this case study the effects on work knowledge caused by automation at a chemical industry is studied, and possibilities for overcoming negative effects of automation with computer-supported learning are explored. The aim is to develop a learning environment where a continuous dialogue on recurring problems in production can support operators in developing better skills to handle production disturbances.

Keywords

Process control work, automation, computer supported learning, tacit knowledge

1 INTRODUCTION

This chapter describes an ongoing case study where the nature of change in work knowledge and work practices caused by automation at a chemical industry is studied, and possibilities for overcoming negative effects of automation with

computer support for workplace learning are explored. The study is carried out at a division of Perstorp AB, an international chemical industry, called Chemitech.

In studies of work knowledge and consequences from computerisation, the epistemological perspective becomes a crucial issue for what problems are addressed and how the study is conducted. Section two presents an outline of the problems being researched in the case study, and the epistemological perspective applied is described in section three. The perspective is mainly grounded in work from the National Centre for Research on Working Life in Stockholm, which has a long tradition in researching effects on work knowledge from introduction of new technology. One important influence in this perspective is Ludwig Wittgenstein's later philosophy, as it has been interpreted and developed by for instance Kjell Johannessen (1990, 1992), Allan Janik (1990) and Bengt Molander (1992). Space does not allow a comprehensive description, but since it has important implications for how operator work knowledge is understood, a brief outline of the perspective is presented. In section four, examples of different aspects of operator work knowledge at the Chemitech factory are described using the chosen epistemological perspective. Finally, the chapter is concluded with a description of how a learning environment is being organised, including the design of computer support for learning, with the aim of overcoming negative effects from automation on operators abilities to handle production disturbances.

2 AUTOMATION AT THE CHEMITECH FACTORY

The problem that is studied can be described as two interrelated parts. The first part concerns the characteristics of operator work knowledge at Chemitech, how it is affected by automation, and the perspectives on operator work knowledge that is held by different actors in the change process. The second part concerns possibilities of overcoming negative effects on operator work knowledge from automation, that are results from decreased contact with the physical production system.

Chemitech produces liquid chemical products, mostly for other branches of Perstorp AB. Out of thirty employees in total, sixteen are process operators divided in three shifts. The production environment is dominated by nine reactor systems where chemicals are produced, and many production processes use exothermic reactions which requires intense supervision. Two of the reactor systems are fully automated, two are partly automated, and the others are operated manually. A job rotation scheme is used with three week periods, where operators switch between the fully automated, partly automated and manual reactor systems. The goal is to have all reactor systems automated in the near future.

2.1 Effects on work knowledge

Numerous studies of work in process industry has been conducted before, describing the nature of process operator work and consequences of automation. Two examples of case studies with different perspectives on operator work are Zuboff (1988) and Perby (1995) who both have researched automation in pulp production. Zuboff

(1988) regards the control room work as detached from the physical production environment, and argue that operators are forced to give up their action-centred knowledge they have developed in manual work, to acquire the more abstract knowledge needed to control a process from a computer system. Perby (1995), on the other hand, argues that the knowledge developed in automated process control is rooted in manual work. She argues that the picture Zuboff (1988) presents, of operators having difficulties in developing the new skills, is only valid just after the automation. According to Perby (1995), learning automated process control in the long term is a matter of reestablishing and maintaining contact with the physical production system, and developing an ability to bridge the gap from the data presented on the screen to the reality on the factory floor. However, there are also, according to Perby (*ibid.*), remaining long term effects of automation that stems from the operators lack of contact with the physical production environment. In order to detect production disturbances, the operators have to be able to "see through" the representation of the process presented on the computer screen, an ability that is difficult to develop. In particular it is important to be able to differ between real disturbances in the process and errors in values presented on the screen due to hardware malfunctions.

From early interviews and observations, the effects of automation on operator work knowledge at the Chemitech factory seem to be well in line with the results reported by Perby (1995). However, the operator work at the Chemitech factory differs from the case studies described by both Zuboff (1988) and Perby (1995) in that operators at all times have to be prepared to switch to manual operation in the case of power failure or loss of compressed air supply. In these situations a backup system for power and compressed air is started, allowing the reactor systems to be manually controlled for a limited time. Reactors with ongoing production processes are then brought to a stable state using manual operations. In this study it is assumed that this makes it even more important for the operators to maintain contact with the physical production environment. Furthermore, it seems that operators employed in the future, who will have very little training in manual process control, does not have the same opportunity to develop knowledge in manual operations. This implies that, in the long run, the ability to handle critical disturbances in production may be eroded, increasing the risk for accidents. In handling unexpected situations, manual work knowledge and judgmental abilities in particular become crucial. Disturbances and problems may appear in endless variations in the production environment at Chemitech, and constant changes in the production system, with valves replaced or moved in preparation for automating the reactors, currently also adds to the complexity. One aim of the study is therefore to provide a clearer picture of the limits of operators abilities to handle critical production disturbances where the backup system is used.

A number of actors are involved in, or affected by, the changing work conditions at the Chemitech factory. Apart from the operators, production management on different levels, and the programmers designing the computer process control

system, are directly involved in the change process. There are also other parts of the organisation that are indirectly affected by the changes. The National Centre for Working Life in Sweden has a long tradition in research concerning effects of computerisation on work knowledge. Bo Göranson (1993) has shown in a number of case studies that the perspective on knowledge held by different actors in the change process strongly affects issues on computer use. Therefore, the perspectives on operator work knowledge held by different actors in the change process at the Chemitech factory will be surveyed in interviews.

2.2 Supporting learning at work

The second part of the case study concerns the possibilities of supporting the operators at the Chemitech factory in overcoming the negative effects of automation on their work knowledge. The focus is on exploring different possibilities in organising a learning environment where operators can improve their abilities in handling critical disturbances in production. This involves designing a computer support for documenting recurring production disturbances and simulating problem situations. In order to get a first picture of the work knowledge needs resulting from automation, unstructured interviews with eleven of the sixteen operators were carried out. A summary of the most frequently expressed knowledge needs is presented in table 1. The results indicate that most operators perceived a need to improve their abilities to handle unexpected situations in production, and in particular situations requiring the backup system to be used. The needs concern knowing what manual operations are needed as well as being geographically well orientated in the different parts of the backup system in the factory building.

Table 1 Areas of perceived knowledge needs according to operators

<i>Knowledge area</i>	<i>Number of operators</i>
Correct actions in emergencies	8
Structure of backup system	6
Handling smaller disturbances	5
Handling equipment failure	4
Orientation in factory	3

From the outline of the research problem above, the research questions addressed in the case study can be summarised as follows:

- What is the nature of the knowledge required for judgement, decisions and action in situations with critical production disturbances at the Chemitech factory?
- What perspectives on operator work knowledge are held by the different actors in the change process?
- What is, from an operator view, the most important consequences on work knowledge from automating production at the Chemitech factory?
- What is the nature of the intervention needed to support the operators in reestablishing and maintaining contact with the physical production system, in order to better prepare them for critical production disturbances?

3 EPISTEMOLOGICAL PERSPECTIVE

There are often borders drawn between knowledge that can be expressed in language, and knowledge that cannot be articulated. In many cases knowledge that can be articulated is considered more valuable and, in the extreme case, the only interpretation of the concept that is acknowledged. According to Johannessen (1992), this interpretation is grounded in logical positivism, and a demand for the unambiguous formulation and empirical verification of new knowledge, but has roots far back in history, for example Leibniz's dream of an "exact language". To accept such an interpretation brings with it the problem that moral, aesthetics, religion etc. must be disregarded as knowledge, and therefore we need a wider interpretation that is better grounded in our use of the terms "know", "knowing", and "knowledge" in different contexts.

In his development of the knowledge concept, Johannessen sketches three aspects of knowledge covering both explicit and implicit properties: propositional knowledge, practical knowledge, and knowledge of familiarity. The first aspect, propositional knowledge, corresponds to theoretical knowledge, or knowledge that can be explicitly expressed in rules, formulas, or theories. Practical knowledge is the action-oriented knowledge we acquire by participating in a praxis. However, we also learn through others experiences and examples in the same praxis, and we gradually develop a judgement for applying knowledge in new situations, where we recognise a similarity to earlier experienced situations. This is the aspect of knowledge that Johannessen calls knowledge of familiarity, which together with practical knowledge constitutes the tacit aspects of knowledge. Practical knowledge and knowledge of familiarity are the link between propositional knowledge and the praxis where it is applied according to Johannessen (*ibid.*), and the latter aspect cannot be present without the other two.

Johannessen (1992) uses Wittgenstein's later philosophy to develop and explain the concept of tacit knowledge, focusing mainly on the nature of rule-following. According to Johannessen, examples are the only means to convey tacit aspects of

knowledge. Wittgenstein points out that language is constituted in praxis, which is evident in aesthetic, moral, and judicial contexts, but this does not necessarily mean constitutive in a conformist sense. When an example of a concept in a praxis is at hand, and where the interpretation of the example is not straightforward, the example has the potential of shifting the established interpretation of the concept. In Johannessen's interpretation of Wittgenstein, the constitutive nature of praxis can therefore be both conserving and progressive. This view of a combination of tradition and progression is also acknowledged by Allan Janik (1990). Using dancing as an example, Janik explains how rule-following behaviour first is learnt through canonical examples, which is shown by someone competent in the praxis. Not until after these constitutive rules have been learnt, can regulative rules and norms be introduced, for example in the form of a notation for the performance of a dance. Janik explains the transitional actions as a result of the constitutive rules being of an analogue nature. Since rule-following behaviour is learnt through imitation, rather than obeying explicit rules, we can find new ways and still be true to the tradition in a praxis. Therefore the constitutive rules can be both canonical and open at the same time, according to Janik (*ibid.*).

Another similarity between the interpretations of Johannessen and Janik is that they both speak about judgement as an important part of competent action in praxis. When an example deviating from the established tradition is at hand, both reflective and judgmental abilities are required. An important prerequisite for the imitative learning is, according to Janik (*ibid.*), to know what is relevant to see in a certain example and a certain situation. We must learn this judgement from a competent practitioner who can point to the salient and relevant elements in particular cases. This 'seeing' must be openminded and unconditional. Janik uses the term 'open-ended concepts' as a necessary precondition for learning. This trust between a learner and an instructor is also present in Donald Schön's (1987) description of the learning process as reciprocal reflection between instructor and learner on each others actions. The learner must have confidence in the instructors' reflections and judgement on the behaviour of the learner. In the next section I will try to exemplify some aspects of operator work knowledge and learning at the Chemitech factory, using the epistemological perspective outlined above.

4 OPERATOR KNOWLEDGE AT THE CHEMITECH FACTORY

In production at the Chemitech factory, there are written instructions for each product describing how the process should be run, with amounts of raw material, temperatures in different stages, and required values for product quality parameters. On the face of it the operator work seems to be just following the instructions, putting in the right raw materials at proper stages, keeping times and temperatures, and at the end check that the product fulfils the quality requirements, possibly with the need of some minor adjustments. However, the knowledge needed for manually operating a reactor system, and running a production process, is like in most professions by far more complicated than just following instructions. It seems clear

that the tacit aspects of work knowledge are the most important for the operators at Chemitech. In the following subsections, some examples of different aspects of operator work knowledge are presented, based on work observation and informal interviews, and related to the three aspects of knowledge described by Johannessen (1990, 1992).

4.1 Propositional knowledge

Some fundamental principles, for example the relation between pressure and temperature, can be said to constitute the propositional knowledge that the operators need, but they cannot be fully understood outside an activity context, and can only function as an ideal model of how a reactor system works. Other fundamental facts are knowledge about different raw materials, if they are in liquid form or powder, where they are stored, where the manual controls are located on the different reactors etc.

4.2 Practical knowledge

The experienced operator uses all his senses in manual operations - looking down into the reactor through a small glass window, listening to flows in pipes, feeling the temperature on a pipe while adjusting a valve, etc. The practical knowledge is clearly expressed for instance in the operations carried out in adjusting for 'vacuum cooling'. By reducing the inlet of air into the reactor, while at the same time pulling air out of the reactor using a pump, the air pressure in the reactor is reduced. This reduces the temperature at which certain chemical reactions take place, which is necessary in many production processes. The operator adjusts a valve to reduce the air pressure, and thereby also reducing the temperature until reaching the level prescribed in the instructions. He does this while carefully listening to the reactor, and while adjusting the valve he switches back and forth between looking at the meters for temperature and pressure. This corresponds to the direct, unreflective activity that characterises practical knowledge in a praxis, or what Schön (1987) calls 'knowing-in-action'.

In line with Johannessens (1990, 1992) different aspects of knowledge, and the argument that knowledge cannot be divided into categories or types, Molander (1992) claims that no knowledge can be completely tacit or completely articulated. Instead we move on a scale from tacit to articulated, where none of the extremes has any correspondence to reality. Adjusting a valve to the right level for vacuum cooling requires tacit knowledge, but it can partly be articulated as rules of thumb or heuristics. At each reactor there is a small 'Post-It'-note with approximate settings for different temperatures. These rules of thumb are used by experienced operators as well as novices. In the same way, the instructions for running a process can be perceived as completely articulated, but uses expressions like 'vacuum cooling at 70 degrees in 25 minutes' where the concept vacuum cooling only can be fully understood from within the praxis. However, the instructions are unarticulated in a deeper sense. The operator makes judgements about external

factors, influencing how the process will be run. The time of year, and the temperature outside affects the temperature of the cooling water going in to the factory (since it is taken from a creek running through the village of Perstorp). By finding out what other process are currently running he also knows the current capacity of cooling water available. He takes all these factors into account in deciding when to start the process in relation to others, and how to run through the different stages.

4.3 Knowledge of familiarity

While vacuum cooling is a good example of the tacit aspect practical knowledge, the aspect knowledge of familiarity is harder to get at. It comes into play in new and sometimes unexpected situations. The operator is then forced to improvise based on experiences from similar situations. This is common because of the infinite variations of disturbances in the normal production process, for instance when a valve jams in a certain step in a certain production process in a certain reactor system. Using Donald Schön's (1987) terms, the operator enters into 'reflection-in-action', a dialogue with the situation where the operator alters between actions and reflections of results from action.

Each unexpected situation becomes a new experience that contributes to the development of the praxis of the operators at Chemitech. The ability of doing correct judgements in handling new situations is strongly connected to the knowledge aspect that Johannessen (1990, 1992) calls knowledge of familiarity. But it can also come into play in decisions during ordinary process control work without disturbances. In processes that are difficult to run safely, a 'vacuum reserve' can be prepared in a vessel adjacent to the reactor, ready to be let in to the reactor to quickly reduce the pressure if necessary. This is not in the written instructions, but a precaution established in the operator praxis, and used for instance in hot summer days when cooling capacity is low. The rule for when to set up a 'vacuum reserve' can be said to be constitutive of safe process control, and requires good judgement and knowledge of familiarity from the operator.

Another situation when knowledge of familiarity comes into play is in the adaptation of process instructions which is done when a new product is introduced. New products are developed in a central laboratory separate from the Chemitech factory, and they are also tested there in small scale. At Chemitech the new products are first run in one of the smaller reactors, and later transferred to larger reactors for production in full scale. At this point, the judgement and knowledge of familiarity of the operators becomes very important. Since the products are only tested in small scale at the product development lab, experienced operators often find flaws in the process instructions which leads to adjustments in the instructions. At the product development laboratory, process instructions are written based on trials in volumes of a few litres, and the operators use their experience to adapt the production process to volumes often a thousand times larger. In the ordinary production work operators also make personal adjustments in

running the processes. These adjustments are often shortcuts that save time for the operator while maintaining product quality, and they seem to be passed on to newer operators in apprenticeship.

4.4 Learning operator knowledge

The manual work knowledge has earlier been characterised by craftily skills, and learning through apprenticeship. After a few weeks in apprenticeship a new operator can normally run one reactor system, but it takes several years to reach a level where you can handle most products on all reactors. One reason for the long learning time is differences between the reactor systems in location of the large number of manual controls. More important reasons are the differences in how processes should be controlled in different reactor systems, due mainly to differences in vessel size and cooling system capacity, and differences depending on external factors such as seasonal air temperature variations.

Since only a relatively small part of the operator knowledge can be articulated, taking part in operator praxis is essential in the learning process, and the tacit aspects of knowledge are conveyed by examples pointed out by the instructor. This is in line with Allan Janik's (1990) description of the learning process, where constitutive rules as the basis for the tacit knowledge, are differed from regulative rules, as the basis for knowledge that can be articulated. Regularity in constitutive rules is learnt through imitation, since there are no articulated rules. Learning to adjust the reactor system for vacuum cooling is one example of operations that can only be learnt through imitation in praxis. Janik (*ibid.*) also uses cooking as an example, which in general seem to be a rather good comparison with the production processes at the Chemitech factory. In cooking, the recipe is not enough to achieve a good result. First you need to learn the basic manual techniques, and they have to be demonstrated since they cannot be articulated in language. When the constitutive rules of cooking are mastered, the recipe forms the regulative rules that guides cooking on a less detailed level. Likewise, the operators learn the basic manual operations through imitation, and only then can they run a process from beginning to end, following process instructions.

Developing knowledge of familiarity is a slower process. By being exposed to a large number of new and unexpected situations, over the years the operators develop judgmental ability based on a large repertoire of examples. However, operator knowledge does not seem to be related to number of working years only. Even experienced operators now and then find themselves in situations which they cannot handle without help from other operators. From conversations and unstructured interviews with the operators, it seems that operator knowledge is perceived as being largely collective. In problem situations operators often rely on experience from the other workers on the shift, and problems are often solved collectively. This view is also supported by data earlier collected by production management to compare how processes are run by the different operators. They concluded that there are small differences within the shifts and larger differences between the shifts when

running a particular process. One interpretation may be that knowledge tend to stay within a shift, and that the different shifts develop their own traditions in work knowledge.

5 COMPUTER SUPPORT FOR WORKPLACE LEARNING

Based on the knowledge needs experienced by operators presented in table 1, and the findings on operator work knowledge as exemplified in section four, possibilities of overcoming the negative effects of automation with computer-supported collaborative workplace learning are currently being explored. The aim is to organise a learning environment, where operators can work on improving their abilities to handle production disturbances during periods with lower activity in production. A computer support for learning is designed in close cooperation with one of the operators, and implemented as a hypermedia system using Macromedia Director™, a multimedia authoring tool. It allows operators to build an interactive model of the physical production system, and then describe examples of production disturbances that can be simulated in this model. The aim with the computer tool is to support the operators in reestablishing and maintain contact with the physical production system, as discussed in section two. It is hoped that this will help them to develop better abilities to 'see through' the representation of the process presented in the process control system, and become better prepared to handle production disturbances. Focus is on working with examples of production disturbances as epistemological tools for conveying experience between operators, both within and across work shifts.

An important question is how examples of production disturbances should be represented, for the operators to be able to relate the examples to their praxis. In the Scandinavian tradition of participatory design of information systems, so called mockups have been used to illustrate properties of a system being designed. In a project on computerisation in printing shops from the eighties (Ehn, 1988), a cardboard box was used to represent a desktop laser printer, a piece of equipment that did not exist at the time. The mockup created the right associations for the users involved in the design process, even if it did not have any functionality at all. According to Ehn & Kyng (1991) mockups become useful when they make sense to the participants '...not because they mirror 'real things' but because of the interaction and reflection they support' (Ehn & Kyng, *ibid.*, p. 177). The interactive model of the physical production system, and the examples of production disturbances, are represented using digitised photographs from the factory environment. As simplifications of reality, they have the same role for the operators in the learning process, as a mockup has for users in participatory design. The main goal is to stimulate reflection and dialogue on common production disturbances, and let operators relate documented problems to operator work practice in order to find possible flaws in how problems are handled.

The computer tool is organised in two parts: the first part allows the user to build an interactive model of the physical production system, and the second part

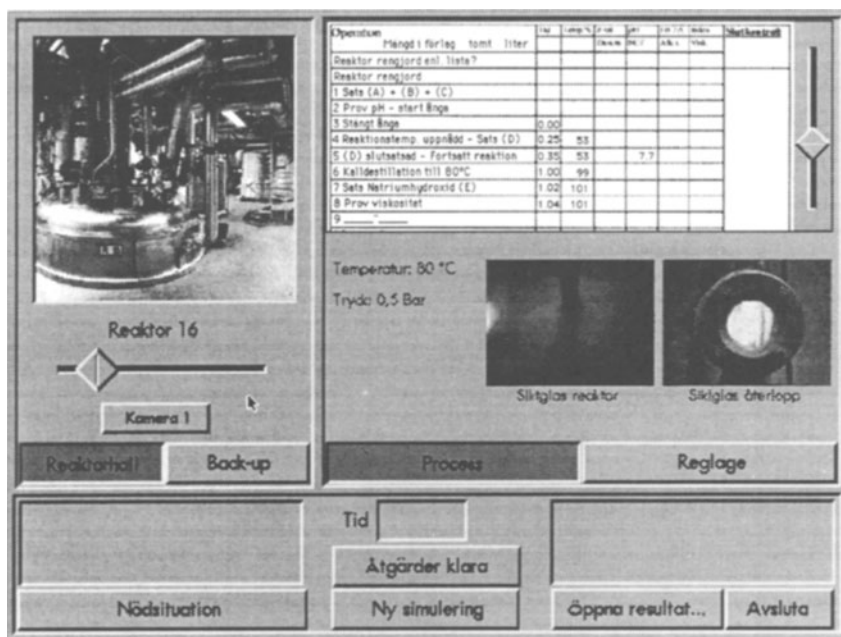


Figure 1. A simulation starts from a randomly generated situation in the factory

provides possibilities to describe specific problems in a production situation. Since small changes are frequently made in the production environment at Chemitech, it is very important that the model is kept up to date at all times. Therefore a digital camera is used, and the images are transferred directly to the computer. After editing, the images are linked in to a hypermedia structure allowing the user to navigate between different parts of the factory by clicking on icons in the images. Components in the machinery can also be zoomed to study details, and for instance valves can be opened or closed by selecting states in a dialogue box. Text descriptions can also be linked to the images for describing functionality, and there is a facility for searching the hypermedia structure, for example by the name of a particular component. In the second part, the state of a production process on a particular reactor system can be described by selecting a step in the written instructions for a process, and filling out values of temperature and pressure. Several such process states can then be aggregated into a production situation in the factory, by adding values for temperature of incoming cooling water and air temperature.

When factory production situations have been set up, problem situations can be simulated using the computer tool. A simulation starts from a production situation in the factory that is either randomly generated or selected (see figure 1). After exploring what processes are currently running on the different reactor systems,

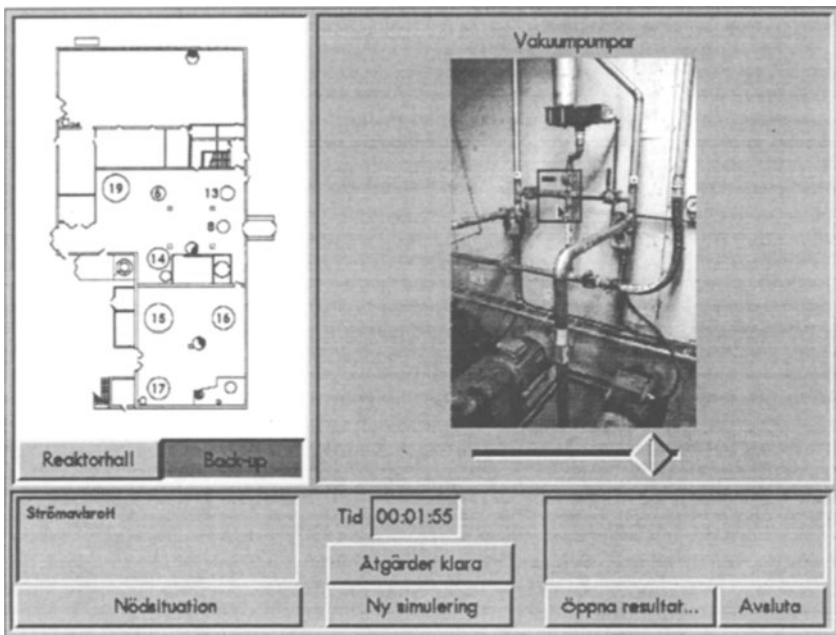


Figure 2: The user interacts directly with the objects displayed

the operator generates a random production disturbance by clicking a button. The appropriate manual operations are then carried out to bring the processes to a stable state (see figure 2). This includes making priorities between the current processes, and invoking the proper parts of the backup system for power, air pressure and cooling water. When all operations are performed, the simulation is stopped by clicking a button, and a log record with time stamps is shown together with recommended operations for the situation at hand (see figure 3). The results can then be saved to disk and printed. Finally, there are plans to provide possibilities for feeding the current situation in the factory directly into the simulation environment for simulating disturbances based on real situations. It will also be possible to set different parameters in the simulations controlling the degree of difficulty.

6 EXPECTED RESULTS

The computer tool will be studied in use for a period of time, with the aim of developing a form for learning environment based on a continuous dialogue on production disturbances and related problems in operator work practice. Observation of the tool in use is carried out at the Chemitech factory, together with both individual and group interviews with operators. The aim is to document examples that illustrate how the tool can support reflection and discussion on different

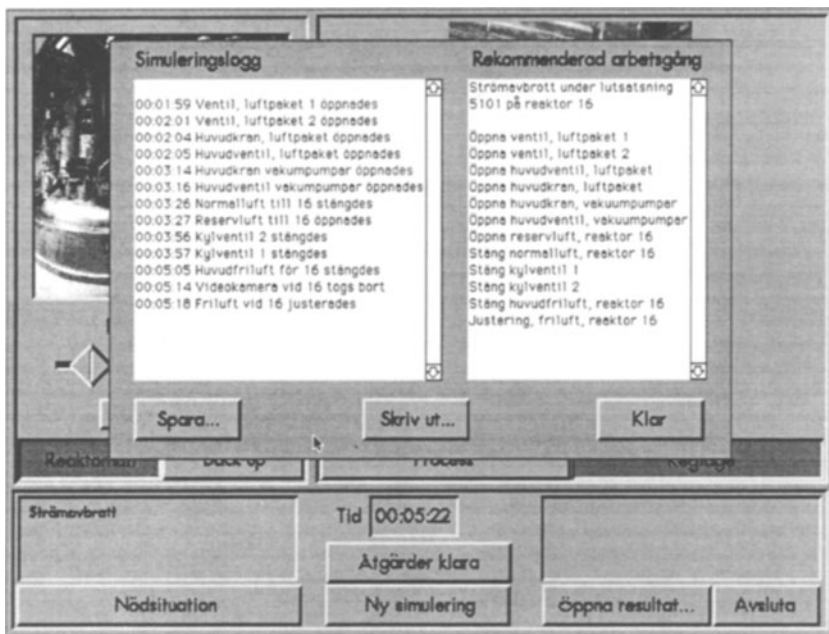


Figure 3: When the simulation is stopped, the logged actions are displayed together with recommended operations.

production disturbances. The main expected result from this case study is an improved understanding of to what extent negative effects of automation on work knowledge can be overcome by organising learning environments with computer support for workplace learning. Other expected results from the study include improved understanding of general consequences caused by automation on operator work knowledge, and in particular abilities to handle critical production disturbances.

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8 BIOGRAPHY

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PART TWO

Simulation Games
in Universities

The role of games in a model company

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Abstract

Professional engineers should be capable of developing innovative and holistic solutions. This constitutes an important challenge to the future engineering education. In a joint project between engineering schools in Denmark a Model Company is being developed to be available on the internet.

Various pedagogical means will be employed in connection with using the Model Company. In particular the paper will focus on the potential role of games for stimulating creative, holistic thinking. To illustrate we shall present a proposed game for creative development of a production concept and outline ideas for two games to demonstrate the virtues and limitations of next generation manufacturing.

This will point to new areas of applying games with the prospect of preparing engineering students for the challenges of the professional engineer.

Keywords

Simulation games, creativity, holistic thinking, next generation manufacturing

1. CHALLENGES TO TEACHING PRODUCTION MANAGEMENT

Teachers of production management are confronted with many challenges in their effort to continuously develop and adopt new teaching approaches and methods to prepare engineering graduates for a professional career. Not only are most universities under sustained pressure to reduce costs and at the same time increase effectiveness. But new market conditions for industrial enterprises request a closer integration of the various disciplines of production, such as production planning & control, production processes, plant-layout, organizational structure and behavior. Furthermore, the production tasks should be seen in a broader context as related to marketing, product development as well as vendors and suppliers in the supply chain. Emerging production paradigms and principles call for a thorough discussion of potential benefits and limitations.

Some of the fundamental challenges are:

- How to give students a comprehensive appreciation of the dynamic nature of production planning & control
- How to train students for the unstructured and non-linear analyses they will have to carry out in their professional career
- How to give students proficiency in practical design of new systems and methods
- How to train students in both re-engineering and innovation.

Over the years many different means of teaching production management have been developed, such as in-class exercises, case studies, simulation and games of various kinds. An overview of simulation games for production management is given in Riis (1995).

In this paper we shall particularly address the third and fourth challenges mentioned in the list above.

There is a general appreciation of project work in the engineering education as a means for developing skills in unstructured problem-solving, integration of different disciplines and teamwork. A grand American program on Engineering Education Coalitions involves a large number of engineering schools in various networks in an effort to develop and implement means for training students in a practical problem-oriented synthesis with the use of teamworking modes, e.g. Coleman (1996). The program was initiated in 1990 and includes several engineering disciplines.

In Europe an increasing number of engineering schools has included project work in their curriculum, as for instance witnessed by the number of visitors to the Aalborg University which has practiced the project work mode extensively since its start in 1974, cf. Kjærdsdam (1994). Most of such student projects take an industrial issue as point of departure; some are carried out at the universities and initiated by a written introduction to the issues more or less building on the tradition of case stories; others involve an industrial enterprise. The latter type has clear advantages

by exposing the students to an ill-structured situation in which they themselves are to gather information and analyze the company to relate performance to the actual operations. This calls for a broad integrative approach to analysis and diagnosis which has often been neglected in traditional teaching. Furthermore, project work in an existing industrial enterprise gives students an opportunity not only to develop new holistic solutions, but also to address the important issue of implementation.

However, the project mode also has limitations. It is time and resource consuming, and the issues, for good reasons, are dominated by the current mode of operations, and seldomly lend themselves to the development of solutions for future production conditions. One of the challenges that we have identified thus has been to develop a pedagogical setting which would capture most of the features of the project working mode, and at the same time be more economical in operations, yet allowing for coping with next generation production systems.

In this paper we shall first present our effort to build a model company and its vision for being able to address a variety of pedagogical situations. Then, three proposed new games will be outlined and discussed with respect to the challenges introduced above. As they are in a preliminary design stage, ideas and alternative directions are welcomed.

2. A MODEL COMPANY

In a joint development project between several engineering schools in Denmark a Model Company is being developed. It will be based on a new product which has been developed, called SnapHane, an equipment for private households to almost automatically brew beer of high quality and with a large variety of different tastes. The product has mechanical and electrical parts and must be able to control chemical processes. A cooling component is essential for securing high quality.

The beer brewing machine is imagined placed in the basement or in the kitchen and has a capacity of 20 liter. The brew may either be served directly as draught beer or bottled. The company will offer kits with all necessary ingredients for brewing a large variety of different tastes.

The students enter the model company in its fifth year of operation and have access to information about the start of the company, its sales for each year, drawings specifying the product, the necessary production processes for the parts manufactured in the company, manufacturing facilities, plant-layout, methods of production planning and control, marketing effort, economical situation, organizational structure, etc.

The data base of the company and its operation in the first five years will be available on Internet allowing for an interconnected presentation of information using hypertext capabilities. To support the students a large model bank is being established with different types of models for analysis and design.

A basic version of the Model Company will be developed in 1997, and a network of European universities is being established with the prospect of broadening the scope of the Model Company and secure its further development.

2. 1 Pedagogical situations to be addressed

The Model Company may be used in many different ways. The primary focus is on integration in industrial enterprises, and the main pedagogical idea is to offer opportunities for students to work with unstructured and complex issues and to experience a more student-driven learning process for non-linear analysis and synthesis. The Model Company should be used as an integral part of other pedagogical means, such as lectures, group discussions, exercises, project work, etc.

We would like to use the Model Company to practice three phases of problem solving, namely

- The Analysis and Diagnosis Phase, in which an understanding of the nature of the issues and problems is sought. It concludes with a structure of proposed focal areas for improvements.
- The Solution Development Phase, in which first a conceptual solution and later a detailed solution are developed. A solution ordinarily includes different aspects, such as production processes, plant-layout, management systems and organizational aspects.
- The Implementation Phase, in which the organization is being prepared for changes, acceptance of the solution sought, and the solutions implemented.

In the basic version we plan to develop a number of exercises aimed at the analysis and diagnosis phase. They will be initiated by the description of a specific incident as a motivation for students to start analyzing the Model Company. For example,

- The sales department has received several requests from dealers to be allowed to offer a discount on model B of 15 per cent. This has initiated the following question from the managing director: "Where do we actually make our profit?"
- Recent difficulties with meeting the promised delivery dates has spurred the production manager to wonder if new bottlenecks have appeared in the flow of customer orders and materials: "Where are the bottlenecks, and what may explain our failure to deliver on time?"
- The managing director has for some time noticed a widespread dissatisfaction in the company, and he senses that conflicts of interest constitute a major cause. Is this true?

The model company will provide a pedagogical setting in which a student is experiencing a non-linear process of analyzing a complex situation in which the student must determine which data would be helpful.

Each of the situations described above may, after the Analysis and Diagnosis Phase, automatically lead to the Solution Development Phase by asking the

students to propose solutions which may cure the identified problems. This will develop skills to re-engineer the Model Company. Such pedagogical activities also will lend themselves to consider the time horizon of various solutions, because inevitably the students would have to discuss whether a proposed solution could be implemented right away, or would presuppose other parts of the company to be changed first. Traditional exercises encourage the development of just one solution which would meet the specified goals. To the contrary, project work in an industrial company will stimulate the students to realize that any acceptable solution always has a time horizon associated as a suffix. In this way several acceptable solutions exist, each of which indicates within which time horizon the solution may be realized.

We believe that working with the Model Company will encourage students to consider a spectrum of acceptable solutions and to also discuss the implementation phase.

In addition to work with re-engineering in the Solution Development Phase, we find the Model Company suitable for dealing with more creative problem solving and for discussing more dramatically different types of solutions. To illustrate the capability of the Model Company to also address futuristic issues we shall outline three games in the next section.

3. SKETCH OF THREE NEW GAMES

It is our experience from working for more than two decades with project work in industrial companies that the students most often perceive the problems that they have uncovered and structured in their analysis and diagnosis as a re-engineering issue. Consequently, they propose a solution which may be implemented within the near future. This is partly due to the interest expressed by the company. Too seldom would the students be challenged to develop a more far sighted solution including a vision of the future company.

We see the Model Company as an opportunity to let students work with more futuristic solutions to prepare them for a professional career in which they have proficiencies in creative systems design.

3. 1 Creative development of a new production concept

The initial situation in this game is the fifth year of the Model Company. The students are told that a year ago the company was taken over by a major brewery with a strong financial capability. The new owner envisages that the current annual sales of 16.000 units within three years with a concerted effort could be increased to 80.000 units. However, this would require that the sales price be cut into one half, yet with increased functionality and quality of the product. Thus, there is a need for creative thinking in terms of developing a new concept for production, marketing and product design.

The situation presented should convince the teams that they must indulge in a creative development process. The current solutions represent a point of departure, but cannot be used for meeting the new challenges.

After an initial analysis and diagnosis each team will be encouraged to identify requirements for the new production system. It may be followed by a “dreaming stage” in which ideas and suggestions of elements of a new production system are developed. Eventually an integrated concept or vision will emerge to be used for a first, coarse evaluation and, if accepted, for developing a detailed configuration of subsystems (production technology, management systems, organization, etc.).

In industrial enterprises and in our lab we are experimenting with the process of developing an integrated, innovative concept or vision, and we plan to continue this effort. We hope to be able to point to means for stimulating this process and would like to also use games as a pedagogical means.

In the game the teams will be asked to develop rather specific plans and expected results for the following year.

To put this exercise described so far into a game context, we propose that each team presents their proposed concept, detailed solution and the expected results to the board of the Model Company. It will consist of experienced manager from industry as well as some of the teachers. The board will question and critique the presentation, and afterwards the game management will use a model to decide the results of the following year (Year 6). This is communicated to the teams and used in their future work, e.g. adjusting the concept, long-term plans and the plans and expected results for the following year (Year 7).

The plans and expected results are presented to the board again followed by a discussion and feedback. The board does not know the decision model, so they are even with the teams. The game management will communicate what will actually happen in year 7.

In this way the teams will learn the effect of their concept and more detailed planning through discussions and feedback from a group of experienced industrialists. We believe that this way of creating a game situation is both realistic and feasible.

Based on our experience from previous games, we see no need for imposing a direct competition among teams. On the other hand, it would be good to stimulate the teams to exchange experience, thus creating a positive learning situation guided by a natural interest in how the other teams are doing.

As mentioned above, the pedagogical mechanism in the game is (1) to let the teams develop expected results of their proposed concept and plans, and (2) to let an experienced group of industrialists give constructive feedback.

3. 2 Next generation production systems

The literature on new emerging paradigms for manufacturing are most often presented as ideals in which the positive properties and characteristics are delineated and no mentioning is made of any limitations. In a class room setting the teacher is left with the possibility to present the claimed virtues and to make an attempt to

differentiate the new paradigm from previous ones. The students would be likely to accept the beauty of the new paradigm and remember the few most important key characteristics for later use as Buzz Words in their engineering career.

If student project work is used in industry, it is our experience that students and their advisors may have difficulty with persuading the company to make experiments with a new paradigm, let alone that the effort and time needed normally exceeds the scope of the student project.

Thus, there is a need at a professional engineering school to offer students an effective and efficient way of learning the advantages and limitations of new emerging production paradigms.

In the following we shall present ideas for using a game in connection with the Model Company to demonstrate two new paradigms, Lean Thinking and The Self-driven Organization.

The idea with the two games is to immerse students into a company which follows the new paradigm. Everything will function according to the ideals of the paradigm. The aim of the game is first to demonstrate how life in an organization is with the new paradigm and secondly to let the students find the limits of functionality. In this way the students may acquire a more comprehensive understanding of the new paradigm than the frequently seen binary assessment in which you are either for the new paradigm or you are against it.

3. 3 Lean Thinking

In the first game described in section 3.1 the Model Company was in its fifth year of operation and great challenges lied ahead. Now the Model Company has successfully moved to its tenth year of operation, and everything functions according to the principles of Lean Thinking. Particular focus will be placed on one or two supply and distribution chains to demonstrate the behavior of interacting, but legally independent organizational units. Our assumption is that if Lean Thinking can be brought to function successfully in such a situation, then it may be applied broadly.

In contrast to many of the usual games we have used and developed, the first step is not to look for ways of improving the system or organization, but to realize what it takes on part of each member of the organization and the needed interplay to fulfill the intentions of Lean Thinking. To support this goal we imagine that in the game IT would be used to its most feasible extent and that most of the interaction between partners in the chains are guided by rules and procedures built into the management systems.

When first accustomed to the lean mode of operation, the players should be subjected to a number of incidents which would help them realize the underlying assumptions and limitations of Lean Thinking. Examples of incidents are:

- A request from a number of customers to decrease the delivery time to one half within a period of six months
- A significant jump in sales of, say 40 %

- The introduction of a new product in the chain, requiring capability changes in the chains

Each group of players in charge of an organizational unit will be asked to analyze their own situation and to react to the imposed changes. But an important part, we imagine, would be to engage participants in negotiations with the other units in the chains.

In this way, the game may help demonstrate and train what it takes to maintain lean thinking in manufacturing. Furthermore, the dimension of learning should also be attended to on the basis of the actual behavior of players in the game.

The game, thus, will provide a setting for demonstrating the necessary prerequisites for a supply and distribution chain to function according to the principles of lean thinking and to realize the limitations of Lean Thinking.

We find that the Model Company will provide an appropriate setting for the game on Lean Thinking outlined. However, not all elements of the company need to be active in this game. We believe that it would be possible to focus attention on just a few links in one or two chains, say altogether five to seven organizational units interacting.

3. 4 The Self-driven Organization

Another area in next generation manufacturing in which it would be useful to gain a more subtle understanding is what we have named "The Self-driven Organization". In recent years, several research groups have developed ideas around this notion, such as Holonic Manufacturing, The Fractal Company, and Bionic Manufacturing. The underlying idea, or dream, is to establish an organization which consists of a number of interacting units, each of which is capable of adapting intelligently to external changes in such a way that the overall goals of the company are achieved. As discussed in a Danish industrial enterprise, we imagine that a worker keeps an eye on what is going on in his group and perhaps also outside. If something unusual occurs, she will on her own initiative seek to adjust appropriately alone or in her group. The notion of self-driven organization captures this feature that each member of the organization takes initiative to adjustments and improvements.

It is hard to find anybody who would object to this idea. On the other hand, little help is available for seeking answers to questions like: What would it take to realize this idea? What is the area of applicability? What are the limitations?

The game to be proposed in this section purports to give participants experiences on the basis of which they may discuss the three questions raised above. It will require that participants work in a group not as a self-contained entity, but as an integral part of the whole organization.

Several settings may be used. We find that the assembly of the Model Company may provide a useful context for a game. We have not yet decided on the type of activities to take place in the group, but some kind of physical activities would help participants to recognize a need for cooperation within and outside the group.

It may be assembly and test of simple pieces of paper, wood, plastic, or the like, representing parts and components of the Model Company's products.

A given assignment of roles may get the group started. But changed demand may suggest a more flexible mode of working within the group. The debriefing periods in-between game sessions should be used to analyze and reflect on the activities of the preceding session. This is an opportunity to discuss the notion of individual responsibility to take initiative and the development of collective behavioral patterns in support of a self-driven mode of operation. The session should also be used to plan the next game session.

We imagine that the group should be supported by advanced IT, including capabilities for learning from past experience.

At the end of the game, players should be asked to dream up the ideal working mode for the group, with respect to both the internal handling of the tasks and the external interplay. This would provide insight into the participants' perception of the self-driven organization.

Much attention in the literature on Holonic Manufacturing is given to cybernetic studies of automatic adoption to externally imposed changes. We find that the focus in this game should rather be on the capability of human players to develop self-driven behavioral patterns. This will require a change of attitude and behavioral skills on part of the participants, but also a capability of the management systems to provide transparency with respect to the role and functioning of the group in the company context.

As has become evident, we are not very far in developing this game. As the concept of the game becomes more specific, existing games should be reviewed for adoption, either fully or partially.

4. SUMMARY AND CONCLUSION

In view of the future role of professional engineers, the capability to develop innovative and holistic solutions constitutes an important challenge to the future engineering education. In a joint project between engineering schools in Denmark a Model Company is being developed to meet this challenge.

Various pedagogical means to be employed in connection with using the Model Company were discussed. In particular the paper has focused on the potential role of games of various kind. To illustrate we proposed one game for creative development of a production concept and two games for demonstrating the virtues and limitations of next generation manufacturing.

In many ways this has pointed to new areas of applying games with the prospect of preparing engineering students for the challenges of the professional engineer.

The effort needed for developing the proposed games is large for which reason we would like to invite colleagues to join our endeavor.

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6. BIOGRAPHY

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Using a participator for teaching modern methodologies of business such as JIT, MRP and cellular organisation

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Abstract

The teaching of JIT, MRP or Cellular Manufacture rarely gets beyond the learning of the vocabulary of the ideas, the claimed advantages on offer and providing an awareness of some of the difficulties. Students - both on degree and executive courses - gain little idea of how to implement the methods and the disruption during transition which they will cause. Equally, going on a site visit where it is claimed that these methods are in use gets little beyond observation of a working practice.

The learning of the ideas can be transformed through gaining an experience of the process and the transition by participating in a practical, if miniature, situation. Far from being just a set of words describing a modern technique, the students are suddenly confronted with the challenge of making sense of the principles in practice and recognising the contextual attractions and difficulties as well as the cultural shock of trying to impose an idea on a set of people who have no knowledge of it. The responses from student bodies and organisations have been dramatic in terms of learning.

Keywords

Participation, simulation, modern methods, JIT, Cellular, CIM

1 THE CHALLENGES IN EDUCATION FOR OPERATIONS MANAGEMENT

The centre ground of the subject of Operations Management has shifted significantly over the last twenty years. Emerging from a history in Industrial Engineering and Operations Research, the subject took the new dimensions of modern methods (fundamentally influenced by Japan), the aspiration to influence strategy (in manufacturing strategy) and the analysis of services from an operational point of view. These new dimensions lifted the subject up to a new significance for teaching within business and for research within management. It rescued the subject from being an extension, often a poor relation, of the technology or engineering function to a subject linking the technology to commercial value. (Anderson, 1995)

However there was also a loss. Although the subject could be presented as new methods and best practice, its centre had moved outside the work place into becoming an ability to comment on the desirable features of the business and the possible modes for improvement. Whereas original subject matter had lost its relevance to the future of the business, the new areas of study had lost their link back to the working in the current work place. The unsolved challenge in teaching Operations Management was how to represent the reality of the operations taking a business standpoint. Students of the subject had moved their stance: from being insiders with no view of commercial value, they had become outsiders with no awareness of the internal work.

Experience of the authors was that a gap was opening up between what was taught and researched and what was needed. Conducting extensive projects with student groups inside businesses, students were found to have very little idea about how to recognise the inside working of the business. Lacking a perception of the "here and now" working of the offices, departments and shop floor of a business the students on arriving and running a business operation, would typically polarise

into one of two views: either the business operation could be run much better with modern methods or that the people working the operations had difficult, impossible jobs with little chance of success. The reality was that students of all ages had no idea how to analyse and perceive a working business operation. The educational and research material was enabling them to comment but not to manage or participate.

The answer to the problem was not simply more teaching of what a business operation is. The abstract description of operations is rather like examining the drawing of a skeleton when the lesson is on the live human being which is being discussed. To some extent the answer might lie in the field trips to working operations and the use of videos of working businesses to capture the relevance and challenge of running and managing the business. But even these approaches are time-consuming and can look simple. The learning can only be done in a participative manner.

Simulations and computer games permit a degree of participation at the individual or group level. The idea of an unfolding situation can be grasped, time pressures and the existence of choices on which judgements must be made. But simulations of the decision making lack the key aspect of reality: actually doing a physical task and, even more demanding, the need to get a collection of other people to do the tasks. The management of operations, as distinct from the study of Operations Management, has to imply the transfer of a decision through the medium of systems, personnel and structure. The idea of experiment, and the risk and problems of communication are central.

The challenge of finding out a mode of learning is of course constrained by several factors. The construction of an exercise must involve a relatively short set-up time. There is no case for having an educational experience which takes a long time to learn how to do it in order to do it. The whole learning package has to be complete within three hours including set-up, learning experience, discussion and conclusion.

A further challenge is to be able to develop a scheme which permits real choices to be experienced but which is still well within the control of the teacher or instructor. It must work with significant numbers of students, force students to do something specific as individuals but still allow the individuals to learn what the group result is. Perhaps the greatest short-coming in management education is the constraints of emerging students only as individuals, rather than in the reference frame of the social and technical groups which form the fundamentals of the complex businesses and the associated management challenge.

Meeting these challenges has been the major aim of the work on Operations Management education at London Business School: “how to bring the management of operational reality into the classroom” in an efficient way.

The guiding experiences have been based on the work undertaken in smaller companies in putting in control and information systems to link the working practices to the commercial outcomes and the twin, if rather schizophrenic, task of educating managers to have a theory of what they do and telling students (and researchers) that there must be a “doing” of what they learn and think.

The next section will describe the initial system called Discovery I which fulfilled the above requirements and which then led on to the opportunity to extend it to the teaching of modern methodologies in a participative experimental manner.

2 THE ORIGIN OF THE 'PARTICIPATOR': THE DISCOVERY I EXERCISE

For the last five years we have used an exercise called Discovery I which fulfils the desired aims of engaging a student body in the Operations Management process. So successful has it been that it is now used throughout all courses as the means of explaining:

- the challenge of specifying the operational system
- the challenge of getting people to do their jobs, in accordance with a specification
- the question of how to evaluate a system and distinguish the commercial result, and the operational result
- the pressure on management to guess at improvements, negotiate approval for change and experiment with the action.

The basis of the whole scheme is apparently very simple. But by compressing time, by involving multiple people with no experience, and by using a computer driven real time system to record and monitor the events as they happen, the difficulty of making the system work is equivalent to the challenge of running an actual business situation. Nearly all the problems are present: physical product tolerance, progressing of orders through the system, confusion about quality, supply chains, commercial commitments and agreements. The scheme has been used extensively with managers in companies and many have remarked on how representative it is of the management challenge of operations as distinct from the technical challenge of operations.

The basic exercise lasts for three hours with half-an-hour's preliminary setup and description. The student (as management) body have to assemble one product to an incoming demand stream. As the work itself progresses through a series of ten steps each with its own specialism, each with its contribution to quality, delivery

and cost, against a time driven requirement, the pressure to succeed is substantial. The whole scheme is monitored automatically by a system of telepads connected to a PC which in turn is connected to a large screen showing status continuously. The student body thus also get a glimpse of how a control system works in addition to the physical task, the working environment and the management process.

The aim of the learning is to demonstrate and test the process of continuous improvement which is so widely proclaimed as a desirable objective. However much of the real purpose is to learn how to specify a configuration of a working system and test it in action on the basis of the improvement process. The real time control scheme produces detailed analysis of what has happened. In effect it is possible to simulate the actual happenings in which the students have been involved. The dominant awareness in this exercise is to become aware of the cycle of how to fit people to a design of a system, how they are in effect testing that design, and how their efforts can be evaluated with a view to improvements of the original design. Rarely has continuous improvement been cast in this light.

3 TEACHING MODERN METHODOLOGIES

The success with the Discovery I exercise in creating an awareness of the challenges of specifying and improving an operational practice led on naturally to the review of its potential for introducing the modern methodologies such as JIT, CIM and Cellular Organisation, TQM etc. (Schonberger, 1988, Sepehri, 1988, Black, 1988) The virtue of moving on from the experience of Discovery I to the new method was that no basic learning would be necessary of the technical product characteristics or the basic construction skills. That being the case, it would immediately lead on to the fundamental questions of the exploration of the principles and the practical use of these systems. Four fundamental questions are:

- How can the principles of the proposed system ideally be translated into the practical realisation?
- How can the transition from the current situation be made at a physical configuration level?
- What different kinds of behaviour must be expected of the personnel and of the line itself, eg what kinds of discipline will be expected?

What can the new system (eg JIT) offer the existing company in terms of market potential, cost effectiveness and improvement in management processes.

In order to conduct this exercise with the right degree of commitment and the educational process was organised in terms of group competitiveness and relevance. The whole exercise was presented in terms of the realistic worry companies have of adopting new systems and the consultative process of consideration and method selection. There are four groups in total. One group was appointed as general consultants to the Discovery I manager (the teacher) and

three other groups were appointed to represent technical suppliers of operational management “answers” JIT, CIM (embodying MRP) and Cellular team based systems. The overall format is shown in Table 1.

Table 1 Implementing Modern Methodologies in Practice - The Discovery II Exercise

<i>Objective</i>	To apply the ideas of JIT, CIM and Cellular Systems to an existing business which has reached its limits	
<i>Method</i>	Team 1	Propose JIT to Discovery I
	Team 2	“ CIM to “ “
	Team 3	“ Cellular to “ “
	Team 4	Provide a basis for assessing the most successful proposal for delivery to Discover I management
<i>Timetable (15 mins)</i>	Team 4	State requirement for a breakthrough in Discovery I
	Teams 1, 2, 3	Organise a presentation (30 mins each) covering: <ul style="list-style-type: none"> • The idea: its concept and framework • The application: what form it takes in Discovery I • The implementation: demonstrate what is required of the people, the disciplines, time controls • The opportunities in the market
	Team 4	Appraise the results and award contract (30 mins)

The first critical point was the role of the general consultant as the appraiser of the offerings of the new methods as presented and tested. The emphasis of the appraisal had to consider how the new system proposed would help ‘the company’ Discovery Electronics break through beyond the limitations of continuous improvement and make the management task simpler. The second critical point was embodied in the fact that the group had to demonstrate the idea in practice on the Discovery Electronics system.

Each group was given some reading on the concept which they had to communicate. To maintain the pace of the learning they were provided in advance with a whole presentation on the scheme for which they had to sell it containing

the provisional detail of layout for the purpose, jobs for the people to do and a flow and control system. They were thus in a strong position to succeed and be convincing in making the statements on technical purpose, organisational requirement and value of the method.

The pressure to succeed comes naturally from the group will to win. But winning required four fundamentals to be delivered:

- the achievement of more profit in the trial run
- the acceptance by the existing workers that they could run it
- the ease of management
- the pressure of future potential externally for a market and internally for flexibility.

To emphasise this last point the three different systems were introduced under the slogans:

JIT:	“let the trays do the work”
CIM:	“leave the stress to the computer”
Cellular:	“teamwork will win over all”

Each technical team had to display a bias and the appraisal group had to consider both the technical merit and the artistic impression in the decision of which scheme to adopt. Experience so far has suggested that any one of the schemes can become the winner of modern methodologies for Discovery Electronics to adopt which leaves the exercise open.

This exercise has been tested four times so far on student bodies from 30 to 50 in number in a three hour time span. The outcomes have given rise to the following experiences:

- an extensive agreement that the students would never have understood what JIT, CIM, or Cellular manufacture meant, without actually doing it or more precisely, trying it out
- an awareness of the difficulty of changing the mind set of the existing personnel. Repeatedly the students tried to copy their existing practices from Discovery I despite their having to take in those practices or a reason to fear change
- a surprise that there were different ways of organising the operation each of which had a unique but coherent set of requirements covering layout, people, flows and controls (Adler and Cole, 1993).

4 RESULTS OF THE EXPERIMENTAL LEARNING

The principal benefit of the learning of modern methodologies within the Discovery II environment has been the clarification of what these ideals and systems have meant “on the ground”. They have answered the question “How

would I recognise a JIT, CIM or Cellular system if I actually saw one?" - a problem not resolved by teaching the characteristics of the techniques as principles away from the practice.

Instead of considering that the systems will be an ideal and must be pushed to the limit of fulfilment, the learning through this scheme has emphasised the transitional nature of change, the implementation effort and the behavioural responses needed both on workers and managers. In this way the learning process has naturally incorporated the implementation questions as part of the education rather than as a separate piece of learning which needs subsequent consideration. (Research writing meanwhile has rather worryingly separated out the challenges of the principle and the implementation problems associated with making them work.) The proposal of the idea and its working practices thus become concurrent issues.

Thirdly the technique of the method had to be considered within the limits of existing technology, know-how and prospects for the business. The judgement of the success of the modern methodology is not simply based on how far it embraces the operations and takes over the business. It has to make its mark up to a point. For this reason, in this exercise, great stress was placed on the appraisal group and on how it distinctly instruments:

- the success of the business
- the success of the technique adopted as a technique
- the success of the adoption process

Failure on any of these dimensions needs to be distinguished. (Leonard-Barton, 1992)

Finally, the students as management groups were able to learn perhaps the most fundamental capability in operations:

- seeing how the system manages the operations and the manager manages the system, and thus achieves the ability "*to manage complexity simply*"
- recognising that management is continually conducting an experiment

The advantage of this real time learning scheme on the use of modern methodologies was that it provided a glimpse of the idea that the manager manages the model - the focused model of JIT, CIM or Cellular organisation - instead of managing the detail. The working practice had to be seen through the framework of the model and ideals as a means of managing greater complexity.

The initial conclusions therefore have provided a basis for a highly efficient mode of learning, in the "learning by doing" idea. We no longer have to teach the ideas derived from the application, derived from the implementation. They can all be

taught as one and indeed different schemes can be compared. The opposing camps in the literature of the new technologists versus the behaviouralists can be recognised and debated “on-site” by the student bodies. The experience reintroduces the fundamental place of negotiation, risk-taking, and vision of operational detail which is so difficult if not impossible to capture in traditional teaching and learning modes.

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Following employment with IBM and the Atomic Energy Authority, he joined the London Business School in 1970. In 1974 Alastair Nicholson became Professor of Operations Management at London Business School. Since then he has worked jointly in education and with businesses on the management of operational systems. Professor Nicholson's principal interests lie in the matching of the management processes to the issues of business profitability and operational effectiveness. The work in this field has been developed with a wide variety of companies in the UK, Eastern Europe and the Far East, often on extended long term projects.

Case based gaming to increase efficiency in global planning processes by multimedia support

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Abstract

Globalization and networking becomes a major issue in factory planning processes. At the same time, information and communication technologies are available which can fasten this process and increase the efficiency of global networking. To teach students and company's employees the handling of these new technologies a case based gaming approach is necessary due to the interaction in planning processes using different information and communication technologies.

Keywords

Factory planning, case study, information and communication technology

1 INTRODUCTION

The increasingly turbulent economic environment forces companies to continuously improve and constantly innovate of their structures and processes. This is reinforced by the growing trend towards globalization, which is the main reason for building up networks (Warnecke and Augustin, 1996). The process of organization design in the field of factory planning is getting more and more complex, mainly because of the

rapidly developing technology and the distribution of resources within networks. Thus, the diversity and dynamics of design processes is steadily increasing.

Also, there is a fast development of *information and communication technology (ICT)*. These new technologies can change the method of communicating in networks and create new structures and processes (Augustin and Förster, 1996).

Factory planning especially will change dramatically through the implementation of ICT in its international surrounding (figure1). Many firms are not aware of this potential to increase their effectiveness, because the work within the networks to solve complex problems as well as the usage of ICT to support networking are only partly implemented in tertiary education. To ensure this knowledge transfer into the companies a special teaching concept has to be implemented in tertiary education: Teaching of theoretical knowledge and the usage in the surrounding of real life situation has to be trained.

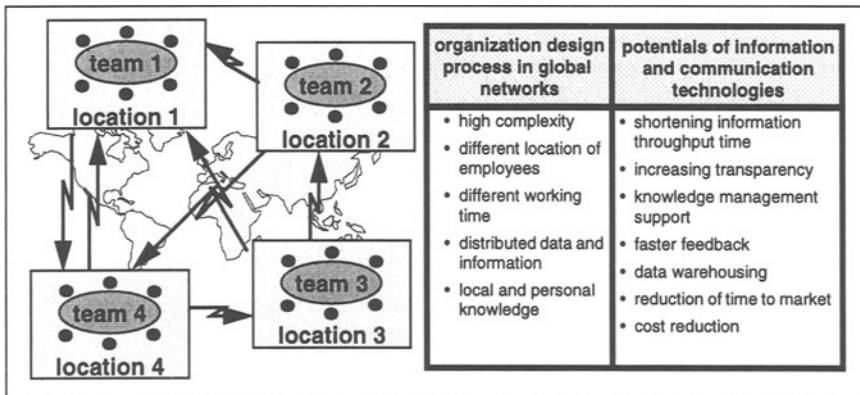


Figure.1: New requirements within global organization design processes and related potentials of ICT.

2 GOALS

To cope with the planning and handling of complex systems a game consisting of different teaching elements was developed, which is now used in tertiary education. This case-based game MinePlan (Multimedia Integrated Network Planning) is designed to eliminate the deficiencies in tertiary education mentioned in chapter 1 and aims at the following:

- The design of a plant-layout based on real life data creates a very realistic scenario and gives the student the experience of real engineering work.
- The process of team oriented problem solving of complex tasks in a short time is being trained, thus building up social competence.

- The gathering of distributed knowledge and the team oriented usage of knowledge is being trained through the implementation of an information system for knowledge management by the group.
- The usage of modern ICT is being taught.
- The students have to evaluate which form of ICT usage is the most effective for a particular planning procedure or a particular form of communication.

3 TEACHING CONCEPT

MinePlan is based on a special teaching structure which includes a various number of teaching methodologies (figure 2):

- Theoretical lessons in the subject of work structuring and logistics design.
- Practical training in using multimedia ICT.
- Exercises to support the understanding of the transformation of theoretical knowledge for practical problem solving.
- A compact course that will enlarge the knowledge transfer in a complex planning situation within an internationally mixed planning group.
- Excursion to the company (real visit or video show) which provided the real life data of the compact course.



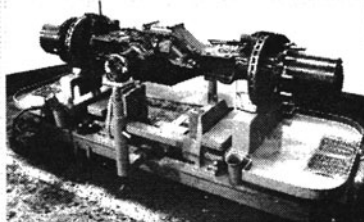
<p>Work Structuring</p> <ul style="list-style-type: none"> <input type="checkbox"/> Definitions <input type="checkbox"/> Work psychology <input type="checkbox"/> Tasks and methods of work structuring <input type="checkbox"/> Work structuring and layout design <input type="checkbox"/> Personnel planning <input type="checkbox"/> Economical evaluation 	<p>Compact Course</p> <p>Planning of an axle pre-assembly segment in the commercial vehicle production.</p> <p>Main Tasks:</p> <ul style="list-style-type: none"> <input type="checkbox"/> Work structuring and layout design <input type="checkbox"/> Definition of logistic components and systems
<p>Logistics</p> <ul style="list-style-type: none"> <input type="checkbox"/> Definitions <input type="checkbox"/> Basics of production control <input type="checkbox"/> Strategies of shop floor control <input type="checkbox"/> Shop floor control in complex logistic systems <input type="checkbox"/> Interaction of shop floor and work structuring <p>Exercises</p> <ul style="list-style-type: none"> <input type="checkbox"/> Problem Solving <input type="checkbox"/> Usage of ICT 	<p>Excursion</p> <ul style="list-style-type: none"> <input type="checkbox"/> Visit of a real commercial vehicle production including an axle pre-assembly segment 

Figure 2: Contents of the teaching concept.

The compact course is the main part of the teaching concept of MinePlan where the theoretical know-how has to be adapted to a real life planning situation and where the students have to make extended use of multimedia ICT to work within the distributed planning team. The planning process is related to the real life planning of a pre-assembly area of a heavy vehicle producer with an additional logistic scenario of supplier interaction. The teams have to develop a new factory and a logistic concept which will be evaluated in comparison to the solutions of other teams and presented at the end of the compact course.

4 USAGE OF ICT

As the teams are placed in different locations, the students have to make extensive use of communication tools such as video conferencing, application sharing, e-mail, telephone, fax etc. (Dier and Lautenbach, 1994; Lewe, 1995).

The support through ICT is based upon the tools shown in figure 3 (Bauerfeld, 1995), only a workflow management system (WFMS) is not used due to the fact that the planning process is based on a lot of ad-hoc decisions and therefore is not well structured enough to be implemented in a WFMS.

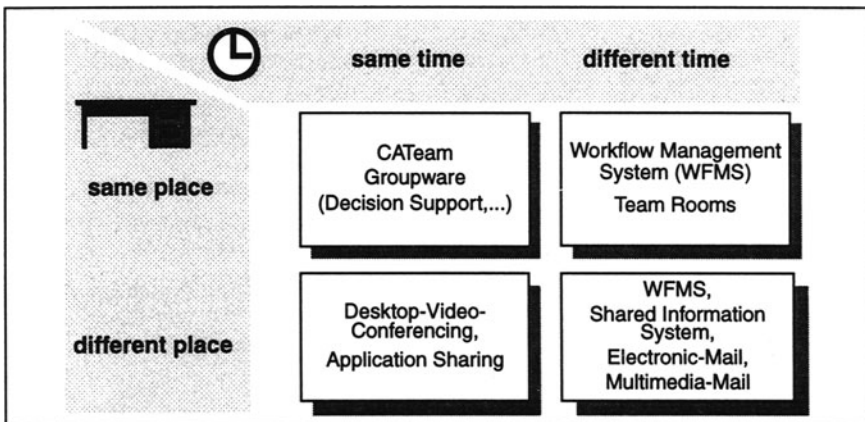


Figure 3: Functionality of CSCW technology.

The basic data for the compact course is provided by a database using a WWW-Browser as front-end. However, certain data is only accessible for the student playing the appropriate role in the game. Logistics data, for example, is only accessible for the student representing the logistics manager. With this, the students are forced to create a network based information system, making it possible for the whole group to access needed information to solve the given problems.

The specific technologies which are used for the realization of MinePlan is shown in figure 4. To reduce the running costs, the video conferencing tools are based on Mbone technology using the internet technology and the transmission in the WIN (German Scientific Network).

	Place	Tool	Description
1. Learning Material	Kaiserslautern (world wide access)	WWW-Server CBT via Internet or CD-ROM	Documentation of theoretical learning material Computer Based Training for the description of planning methods and technical machinery and tools used in the factory implementation
2. Discussion Forum	Kaiserslautern (world wide access)	News-Server	Supervised News Group to discuss questions and ideas on the subject
3. Basic Lessons	Kaiserslautern		Frontal lessons
4. ICT-Exercises	Kaiserslautern	Conferencing tools - Video Conferencing (vic) - Visual Audio Tool (vat) - Session Directory (sd) - White Board (wb)	Lesson to learn the use of the different ICT tools
5. Compact Course	Kaiserslautern and Darmstadt	Conferencing tools (see ICT exercises)	Planning in a distributed team
6. Working Material	Kaiserslautern (world wide access)	WWW - Server	Data Sheets, Layout plans personal information,...

Figure 4: Tools in the MinePlan environment.

5 THE GAME

In the first stage of development, which was oriented on an explorative prototyping process, the game MinePlan was hosted by the FBK (Institute of Manufacturing and Production Management) in Kaiserslautern and the GMD (German National Research Center for Information Technology) in Darmstadt. The groups were split into two teams, consisting of three and two participants, who were placed at two different locations (figure 5).

The groups had to perform both single-person tasks and joint-group tasks. The distributed information made interaction between the groups necessary, especially in tasks like layout-planning. Therefore, conferencing tools were used extensively.

The supply of information was personalized using the WWW with passwords (figure 6). With this, each group could build up its own Knowledge Based Management System through joining their information, using the different methods and tools for CSCW.

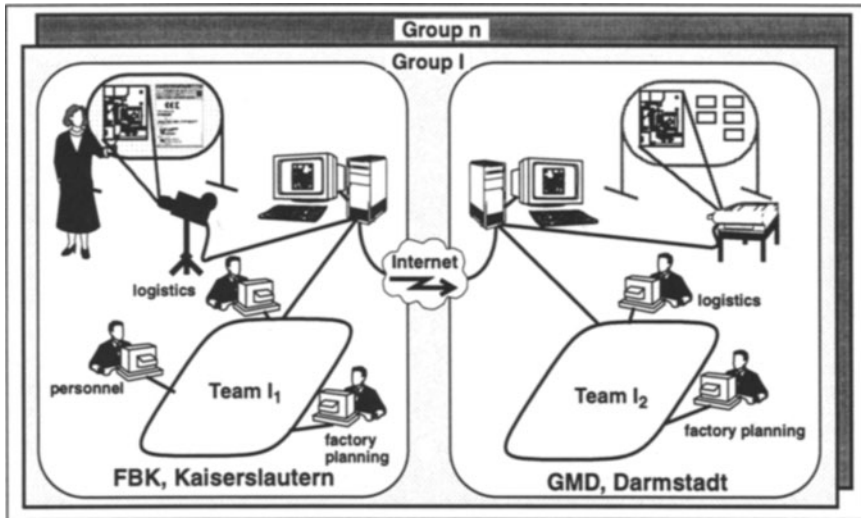


Figure 5: Information technology usage in the production design process.

6 RESULTS

The case-based game has already been played with groups joined together in one location and all the stated aims of the game have been reached (Augustin, 1996).

The compact course was initially held as ICT-oriented game in June 1997. Furthermore, the distance between Darmstadt and Kaiserslautern made face-to-face communication impossible, forcing the students to use communication tools.

For the evaluation of the game concept, the following points were evaluated during and after the compact course:

- Did the students manage to solve the problems without face-to-face communication?

The students were able to solve the problem in a much more efficient way. To communicate by video-conferencing or an application sharing session the students had to be well prepared. Due to this, the students came to faster decisions in each ICT supported meeting compared to the groups communicating face-to-face. The way of cooperating was more aim-oriented.

- How long did the group take to socialize? Did the usage of ICT help? In which situations would a face-to-face communication be helpful?

It took one day to socialize in the group. After this, the video signal was turned off most of the time and application sharing with audio-conferencing were the preferred tools. The usage of ICT helped, as mentioned above, to work in a more

structured and efficient way. For the socializing process, a face-to-face meeting would have been preferred by the group.

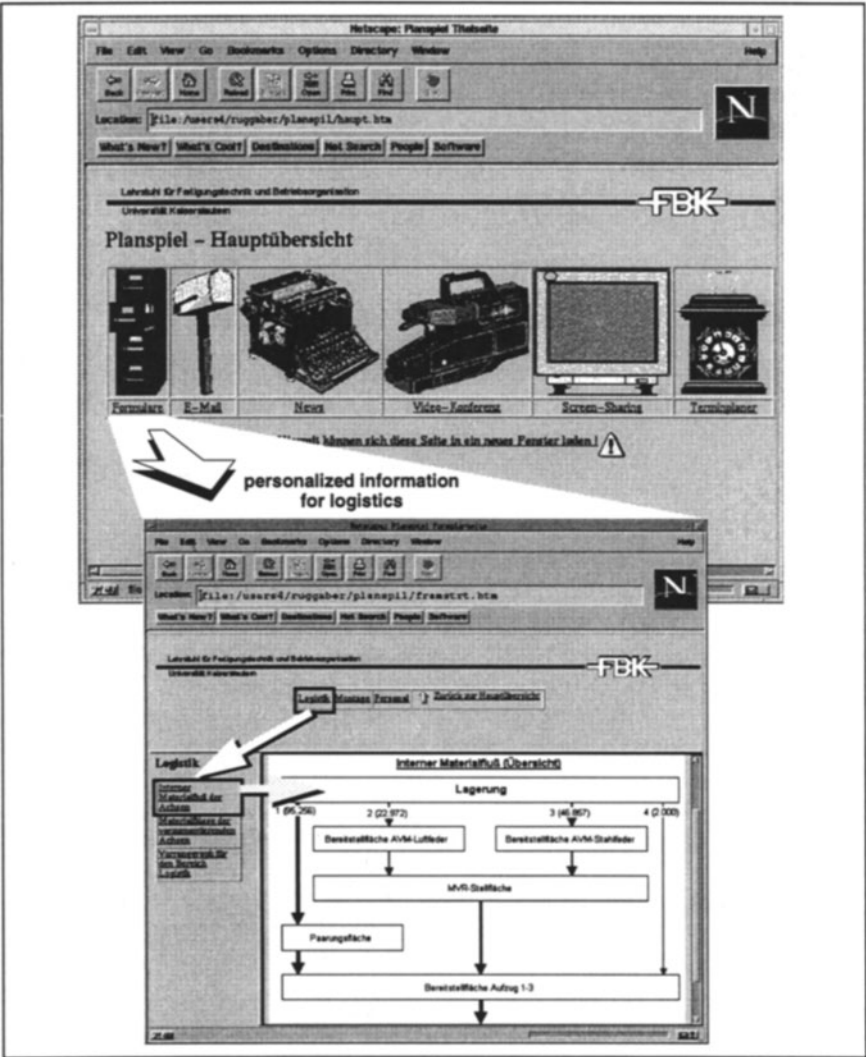


Figure 6: Implementation of personalized information supply using WWW-technology.

- Did the students use different communication tools for the same problem? Did an evaluation for the best method take place in the group?
The learning effect influenced the usage of ICT. In the beginning, video has been a very important tool to socialize. After the forming and storming phase, the group concentrated on application sharing, news group and audio-conferences to support the performing of the game. Different applications were used for specific tasks which showed a learning during the game.
- Which conflicts occurred? Were they due to the distance between the members of the group? Were these technical problems caused by the communication tools? Or were these social problems?
Only technical influenced problems occurred. Due to the fact that the bandwidth in the Internet can't be reserved, the video conferencing session often ended with a network break-down. Also whiteboard sessions were influenced by small bandwidth: Sometimes the group couldn't receive all signals on the whiteboard which caused misunderstandings.
- Was it possible to design a Group Knowledge Based Management System for the group and what were the main restrictions to fulfill this?
The students did not put together all their information in a shared knowledge database. Therefore they used the newsgroups to supply everybody with all information and data.
- How much did the results of the distributed groups differ to those of the locally placed groups in Kaiserslautern?
There were no major differences in the results of the groups.

All evaluations led to the conclusion that the planning task can be well supported by ICT and fulfilled by distributed teams. For the socializing process a face-to-face meeting at the beginning seems to be necessary to increase the efficiency of the planning task.

7 KNOWLEDGE TRANSFER

The changes in the industrial environment mentioned in the introduction are implemented in the game concept and offer the students the possibility to gather practical knowledge and experience.

The compact course should give students a feeling of the potentials and limitations of ICT usage and, more important, demonstrate how important communication for team processes is. This knowledge can only be gathered through experiencing in a compact course, because communication can only be trained in practice and can not be theoretically taught.

After the first stage of implementation in June 1997, the MinePlan concept is planned to be extended to various universities in Europe. The pan-European partici-

pation will give students the opportunity to work within an international team using the English language to communicate. The students will be placed in an international network in which they can work without moving physically so that a virtual reality with a real life background emerges.

The transfer of this knowledge to industry is first of all realized through the qualification of future engineers and secondly by offering companies the possibility to participate in the compact course, so that direct knowledge transfer can take place.

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9 BIOGRAPHY

Harald Augustin, born in 1967, studied at the Technical University of Karlsruhe, Germany, and abroad in Australia, Canada and France. Since 1993 he works as a research assistant with Prof. Dr.-Ing. G. Warnecke at the Institute of Manufacturing Engineering and Production Management FBK at the University Kaiserslautern, Germany, where he received his Ph.D. (Dr.-Ing.) in July 1997 and where he holds the position of a chief-engineer since 1996. His research subjects are production process modeling and information logistics.

INSIGHTS - Integrated simulation game for a comprehensive redesign of production systems

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Abstract

The integrated simulation game for planning and reorganizing production systems has been developed at the ifab-institute in order to engage the awareness of the players for actual problems in real production systems. During the planning game the participants have to act on operative level as well as on strategic issues. First they have to plan and control the production of an existing assembly system for producing bicycles in planning teams. The system is modeled using the simulation tool FEMOS. Running the factory the teams are going to detect weak points inside the existing system. This experience is the basis for reorganizing the assembly system afterwards. The paper consists of demonstrating the principle structure of the planning game, the material used as well as an illustration of different planning results obtained by playing the game with students and professionals.

Keywords

Simulation game, production planning and control, redesign of production systems, computer based

1 INTRODUCTION

The game being explained in the following is called INSIGHTS, which means integrated simulation game for a comprehensive redesign of production systems. It was developed at the ifab-institute during the CAESAR project which is part of the programme LEONARDO da VINCI of the European Commission. The objective of the game is to engage the awareness of industrial managers for actual problems in real production systems. These problems are caused by strong market changes and an increasing competition on the market. So the industrial companies are forced to adapt their activities on operative as well as on strategic level. Therefore, the participants have to act on operative and strategic issues during the planning game concerning an assembly system for bicycles.

This application field has been chosen due to the well known product with an adequate product complexity. Because of the familiarity of bicycles and their components, the participants are not forced to spend too much effort in analyzing products and their bill of materials. On this basis the participants can fully concentrate on the organizational problems inside the production system which is modeled using the simulation tool FEMOS (refer to Zülch, Grobel 1996). By running the factory in a simulation model, the participants have the opportunity to recognize the impact of their planning solutions on the dynamic behavior of the production system.

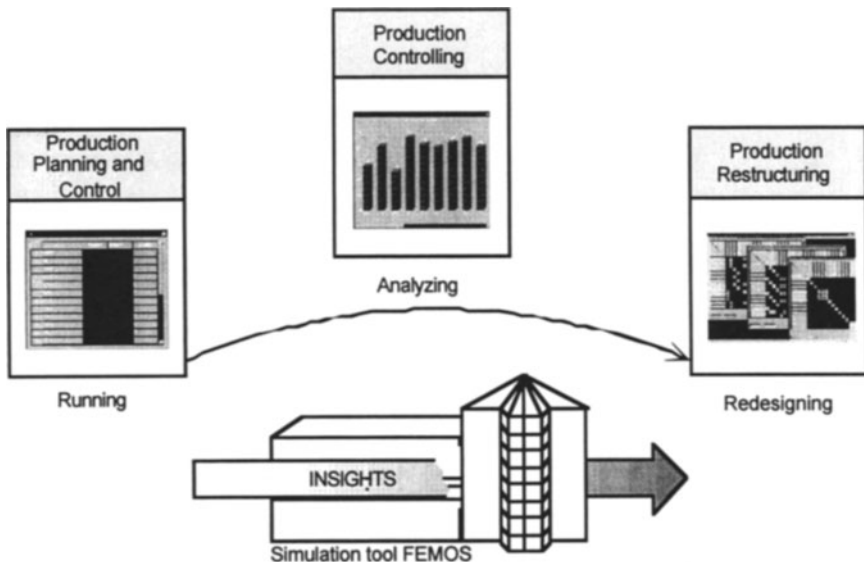


Figure 1: Structure of the planning game

The global target of the planning game is to allow a better understanding of running a factory, analyzing the existing situation and finding solutions for a better performance of the production system by reengineering it.

Therefore, the planning game is separated into three different modules, namely the production planning and control (PPC), the production controlling and the redesign of production systems (cf. figure 1). These modules deal with adequate problems in order to improve the understanding and knowledge concerning production systems in general. The modules represent different aspects in production management which can be investigated independently. This is the basis for an optimal adaptation of the seminar to the needs of the participants.

By teaching students and professionals in production management and applying simulation supported seminars during several years, these topics have been proved as very important for a good understanding of reengineering and its future application by the participants.

The modules are defined as single running modules. This means every part is running on its own and can be chosen as stand-alone seminar. Each module is split into a theoretical lecture and practical planning work. This work is performed within teams of 3 to 4 participants.

As computer platform standard Personal Computers were chosen in order to design the planning game as flexible as possible. Due to the broad installations of the graphical operating system Microsoft Windows, the simulation program is running under Windows95. On this basis the seminar can easily run in every company or university without high preparation effort.

2 PRODUCTION PLANNING

The first module in the normal sequence of the planning game is running a simulated bicycle factory by means of production planning and control. The objective of this part of the seminar is to confront the participants with standard problems in running a factory as they occur in real life. In order to recover the present knowledge and to balance the relevant learning, the participants follow a short lecture of production planning and control theory. Parts of the lecture are on the one side general logistical aspects such as lead time reduction or increase of utilization and on the other side monetary criteria of productivity. Furthermore, the interdependencies of the different logistical aspects and the most common strategies of how to achieve the expected goals are presented and discussed. This lecture is limited to the practical needs of reality as well as of the planning game in order to keep the theoretical part of the seminar as moderate as possible.

After the theoretical part the participants are faced with the concrete planning case of the bicycle assembly. Therefore, they follow an introduction by the lecturer concerning the principal structure of the bicycle assembly and the products. During this introduction the different areas of bicycle assembly e.g. the wheel assembly, the pre- and final assembly etc. and the assigned tools and personnel are presented. Furthermore, the participants learn the details of the final products, the three bicycle types standard, trekking and mountain bike, and their components. During this introduction various information packages, including the necessary information about the processes, the processing times and their precedence relations are made available. Besides the process documentation, descriptions about the parts and the parts structure of the different products and components are

disseminated to the participants. Additionally, all information about the existing functional organization of the assembly line is given to every group. During this part of the seminar, the participants are not allowed to change the organizational structure of the assembly.

After the analysis of the disseminated information material, the participants are faced with a specific demand for the three types of bicycles for the present period as well as with forecasts for the following periods. On this basis the participants have to determine the production orders for finished and semi-finished products considering their lot sizes and release times. In addition, they have to calculate the needs of purchase parts in linkage with the determined production orders (cf. figure 2). Due to some multiple use of purchase parts and components, the demands for the three bicycle types can not be analyzed separately. For example, the same spokes are used in all bikes and further on, the same wheels are used in trekking and mountain bikes. Handling this simulation the awareness of the participants is improved for this kind of problems which are occurring in several other production areas. Furthermore, the purchase is restricted by some predefined rules concerning the delivery times of economical normal and expensive urgent orders and their respective standard deviations. Also quantity discounts are given by the suppliers of each purchase part exceeding a specific number.

Besides the planning of production and purchase, the capacity adjustment on a static basis has to be done by the teams. This is prepared by calculating the expected capacity needs and comparing the results with the existing resources. The adjustment can be done by using overtime hours or introducing additional shifts for specific workplaces.

Afterwards, the teams run the simulation tool for achieving the results of their planning solution by analyzing the dynamic behavior on the PC. For example, the participants can see the difference between their static capacity calculation and the dynamical utilization in the simulation run. Also, the success in planning the purchase and the production orders is shown by the simulation run.

Depending on the duration of the seminar, the participants have to plan a certain number of periods which equal to one week in the simulation run. Moderate numbers of periods are three to five. Less than three periods means the participants do not have the chance to modify an ineffective strategy and after five periods the additional educational gain tends to decrease.

During this PPC-module of the seminar, simulation is used for demonstrating the behavior of a real production system by running it on the calculated data of the teams. Mistakes which occur during the planning phase and are detected in the simulation run should be corrected during the following planning periods similar to reality. This means the participants are not allowed to correct the planning data of the actual planning period and repeat the simulation run for the same period.

Purchase Orders

	Part	Quantity	Order day	Priority	Status
0	HA65 TR	1000	0	ES	stop
1	HA67 M	1000	0	ES	stop
2	FW69 S	1600	0	ES	stop
3	W10 STM	900	0	ES	stop
4	FW12 S	1200	0	ES	stop
5	FW14 TM	1200	0	Normal	FW1
6	FW15 TM	900	0	ES	stop
7	RW17 S	1000	0		
8	RW18 T				
9	PD28 ST				
10	PD21 ST				
11	HA 1				

Production Orders

	Product	Quantity	Start day
0	HA S	100	0
1	HA M	100	0
2	PD STM	100	0
3	RW S	10	0
4	PA M	100	0
5	IA T	100	0
6	FA S	100	0
7	FA M	100	0
8	GC S	10	0
9	GC M	100	0
10	FW2	100	0
11	PD 2	100	0

Sales

	Part number	#Orders	#Orders	#Orders
0	HA67	2	0	1
1	HA 1	1	0	1
2	HA 2	1	0	1
3	HA 3	1	0	2
4	HA 2	1	0	6
5	HA 3	1	0	3
6	PD 1	1	0	7
7	PA 1	1	0	2
8	PA 2	1	20	8
9	PA 3	1	10	7
10	PA 4	1	30	7
11	HA 1	1	0	1

Figure 2: Input masks for the planning data

3 PRODUCTION CONTROLLING

In order to identify potentials for improvement, performance evaluation of production systems is a topic of growing importance to companies. Therefore, this next part has been added to the seminar in order to introduce the participants to the theory and practice of performance measurement.

After running the assembly line for a few periods, the participants learn more and more to run the bicycle assembly with the given information of the simulation runs. During the PPC-part the evaluation information has been limited to a defined level in order to not confuse the participants. The experience gained during planning the production leads to an increasing demand of more detailed information concerning the tracing of the simulation behavior and the afterwards evaluation on different points of view. This is the initial point for instructing the participants the theory of production controlling. Therefore, the production controlling module consists of three aspects:

- statical analysis of the existing production structure,
- tracing the simulation run and
- analysis of the simulation results.

All aspects concentrate on logistical and monetary evaluation of production systems. The statical analysis deals with performance indicators which describe the

organizational structure (e.g. number of functions assigned to the personnel), the parts structure (e.g. the size of the parts tree structure) and also the precedence structure of processes (e.g. number of processes which can be operated in parallel in relation to the total number of processes). The presented indicators provide a condensed view of the existing system and can be applied e.g. for controlling the existing system or for benchmarking with other production systems.

Besides the static evaluation of the production system, the participants learn how simulation can be applied for a dynamical analysis during and after the simulation run. During the simulation run, the system provides several possibilities of tracing the operated processes and the involved resources of the production system. Therefore, e.g. detailed representations of work places, personnel, stocks or waiting queues can be selected by the participants and visualized on-line during simulation.

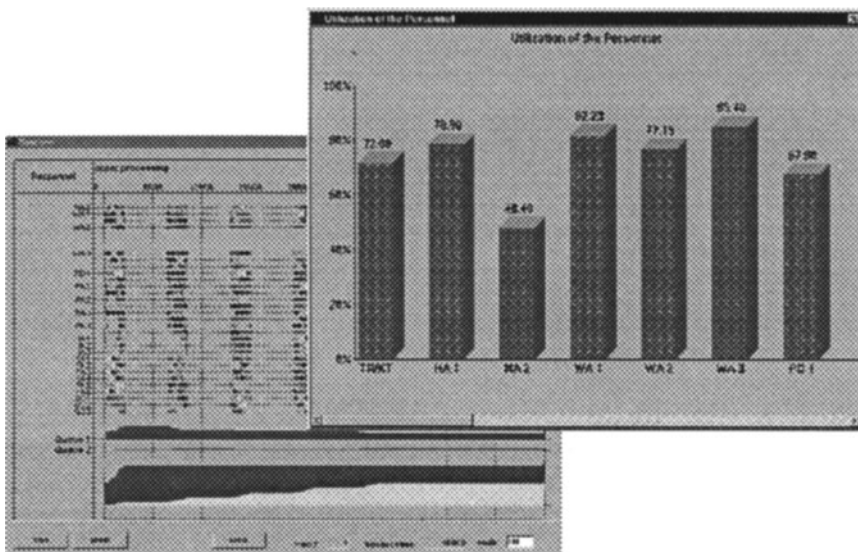


Figure 3: Tracing simulation and dynamical analysis of the production system

After tracing the simulation run a wide range of performance indicators for the analysis of the simulation data is at the disposal of the participants. Logistical aspects e.g. the utilization of the individual resources can be investigated as well as costs for machines or personnel up to total activity based costing indicators by using the evaluation tool set of the simulation system (refer to Zülch, Brinkmeier 1996). On this basis, the participants get an impression of the interdependencies between different logistical and monetary goals and how to achieve specific objectives with different planning and control strategies. Just-in-time delivery, maximization of utilization or short lead times are examples which can be analyzed.

While simulating the starting solution with the existing organizational structure and applying the indicators of the evaluation tool, weak points of the starting solution are detected and ideas for potential improvements are developed by the participants. This is the initial point for the third part of the seminar concentrating on production reengineering.

4 REDESIGN OF THE PRODUCTION SYSTEM

After getting an in-depth look into the structure and the problems of the existing bicycle factory through the planning and the controlling part of the game, the participants get the opportunity to improve the situation substantially. The main objective of this part is to face the participants with possibilities and requirements of new forms of work organization, e.g. segmentation, group work, outsourcing etc. The scenario of the game is, that the market demand will increase about 25 % and that the existing structure is not able to cope with this situation. Therefore, each team has to design a new work structure which improves the existing situation and is able to satisfy the new demands.

An important point is the evaluation of the solutions that will be worked out by the different planning teams. In order to consider not only monetary but also non-monetary criteria, a so-called dual evaluation is used (refer to Grob, Haffner 1982). While the monetary evaluation is based on an investment calculation, the non-monetary criteria are evaluated by means of benefit analysis. Thereby, especially those criteria which are difficult to quantify (e.g. quality improvement, worker's satisfaction) can be taken into consideration.

In the initial situation, the work structure is functional oriented and divided into several assembly blocks (e.g. handle bar assembly, pre-assembly, quality control etc.). In order to give a starting point to the planning teams, they first have to decide whether to introduce a product-oriented segmentation or group work structures instead of the initial assembly lines. This decision must be taken for every assembly block separately. Furthermore, it is possible to join the assembly blocks into greater units. For example, it is possible to define three large production segments, one for each bicycle type, which cover the whole production process. The choice of a principle work structure is intended to give a frame to the following planning tasks. Further adjustments of the structure are possible and due to the generic definition of the underpinning simulation system, virtually any form of work structure can be designed and simulated.

Usually, the next step for the redesign of the production system is the analysis of the work flow. The flow of production orders through the system is planned based on activity networks (refer to Zülch, Brinkmeier 1996) as shown in figure 4. These networks mainly describe the technological precedence between the assembly steps as well as their work content. Both information are essential for the planning procedure. Based on these activity networks, a first approach for the assignment of assembly steps to work places can be made.

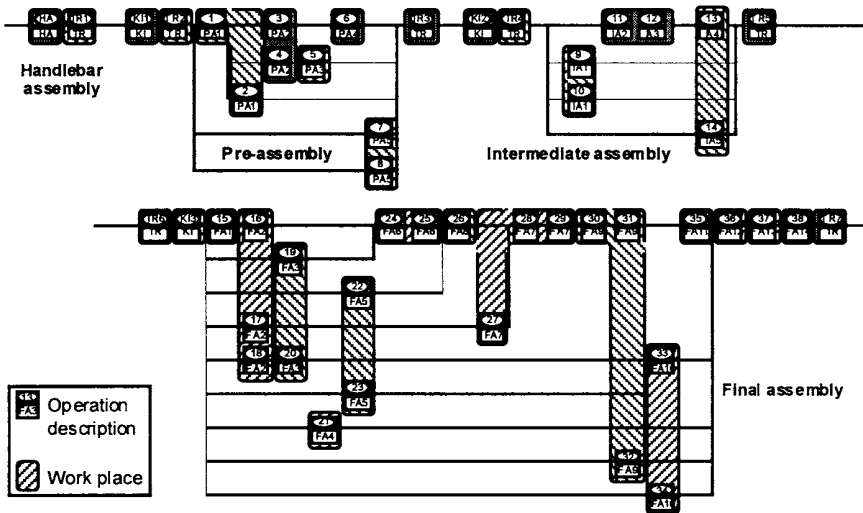


Figure 4: Planning of the work flow

The work structure itself is modeled through three relations, which are represented by three input matrixes (cf. figure 5):

Feasibility:

This relation between assembly operations and work places describes, at which work places each individual operation can be performed. For example, in a production line usually every assembly step is assigned to its own work place. By contrast, in a group work structure many operations share the same work place. If more than one work place is assigned to an operation, a priority must be defined.

Competence:

By this relation the personnel is assigned to the work places. Therefore, it defines which person belongs to which assembly unit (segment or group). Furthermore, it is possible to share person between units. In this case, it is necessary to define a priority ranking for the assembly units.

Ability:

The third relation between personnel and operations describes, which person is able to perform a certain assembly task. Thereby, it defines the qualification structure of the labor force. The assembly tasks are grouped into several qualification levels. By assigning a number of tasks of the same qualification level to a person, job enlargement can be achieved. The assignment of tasks with higher requirements to a person leads to job enrichment. Both measurements result in qualification costs and possibly also in higher wage rates, so the planning teams have to evaluate carefully, whether these additional costs are justified e.g. by a higher productivity or other advantages, such as shorter lead times.

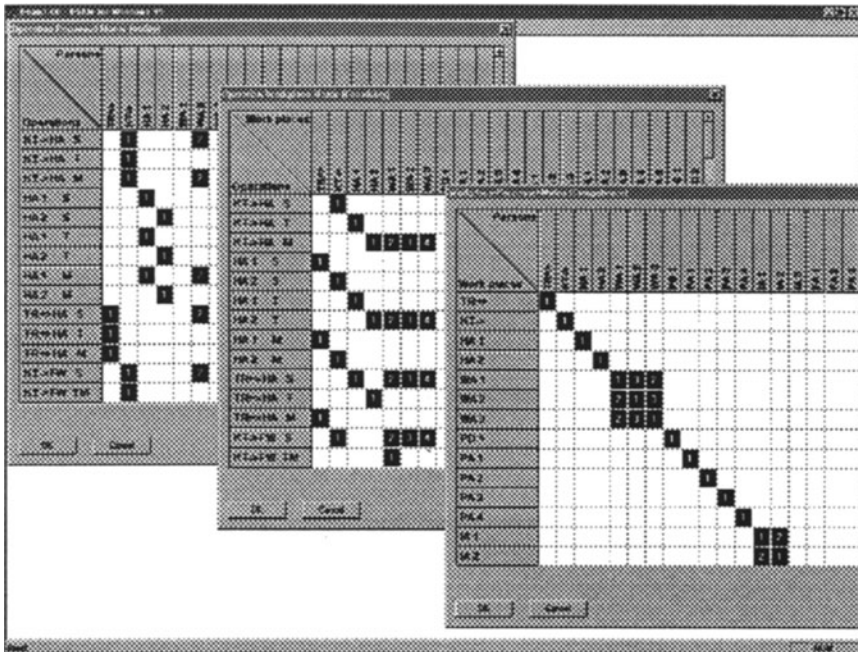


Figure 5: Modeling of work structures

Another issue of work structuring in the planning game is the outsourcing of components. Figure 6 shows the outsourcing of the wheel production and its effects on the bill of material. By outsourcing specific components, the planning teams can dramatically simplify their structure but on the other side they have to deal with new problems caused by the dependency from the supplier. The process of outsourcing starts with negotiations about the price between the planning team and the supplier (represented by the lecturer). For this, a good knowledge about the production costs of the involved components is required. The teams have to decide whether and for which components outsourcing is economically sensible. After taking the decision for outsourcing, the simulation model is adapted. The related components and production facilities are removed from the system and the outsourced component is transferred into a usual purchase item. This means, it has a purchase price and a certain distribution that describes the delivery characteristics of the supplier.

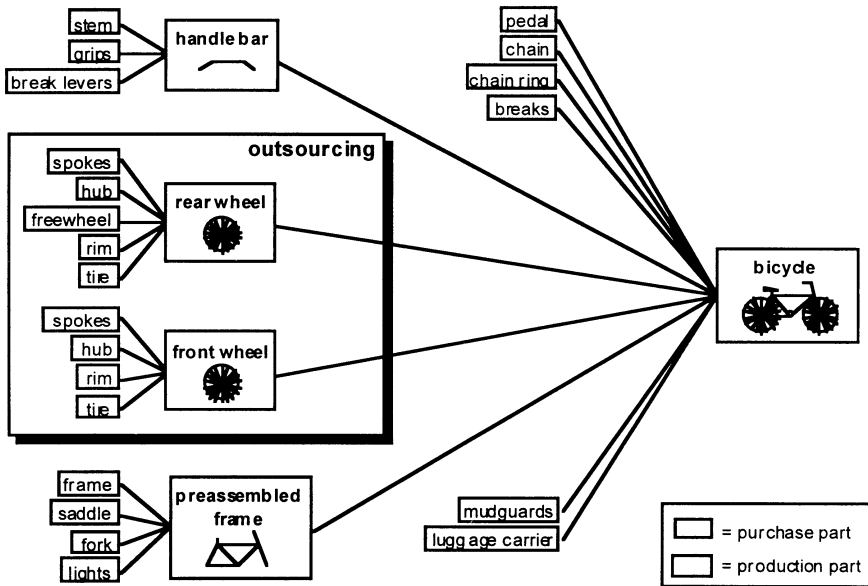


Figure 6: Outsourcing of components

Besides the basic modeling aspects, the planning teams also have to develop a layout in order to visualize their new work structure. Especially those aspects, which are not covered by the simulation, can be visualized. This layout shall include

- design of work places,
- recreation areas,
- layout of the material flow,
- security issues (e.g. emergency exits) and
- other human aspects.

After the new work structures have been worked out, the planning teams model their individual solutions using the simulation program FEMOS. Thus, they have the opportunity to perform several simulation cycles in order to incrementally improve their solution. This improvement is based on the various monitoring and controlling capabilities of the simulation program which already have been introduced during the second part of the seminar.

When the solutions have been finished, they are finally evaluated based on the criteria which have been already fixed at the beginning of this seminar part. While the monetary evaluation is done through a simplified investment calculation, the evaluation of the non-monetary criteria is based on a benefit analysis. Thereby, the criteria are weighted against each other and the degree of fulfillment is determined

for every criteria. Based on this, a so-called work system's value is calculated which quantifies the non-monetary benefit of the solution. Both, the monetary and the non-monetary value are then used simultaneously to evaluate the solutions of the planning teams against each other.

5 PRESENTATION OF THE SOLUTIONS

The last step of the seminar is the presentation of the different solutions. Therefore, the teams have to prepare a number of flip charts and to present their ideas, strategies and results in front of a fictitious "board of management". The presentation is usually separated into the production planning and control and the redesign part. This means the groups have to prepare separate presentations for these two seminar parts. Usually, the presentation is directly after the relevant seminar module. On this basis, all teams have the chance to see the strategies and results of the other teams.

This part of the seminar is to give the participants the experience of explaining their results to the management and other responsible persons which may not be in favor of their solution and have to be convinced. Students as well as professionals shall learn how to present and defend their ideas concerning logistical and monetary aspects.

6 TARGET GROUPS

The seminar is designed to fit the needs of educating students in a practical way as well as teaching professionals in order to commit them to detect existing problems in their own production sites. Students learn the principle theory of the different topics and furthermore, they gain some experience in applying the theory in a practical planning environment. Due to the theoretical orientation of studies at universities students have a real chance to run a simulated factory on their own and to apply own ideas for improvements. The experience has shown that students are highly motivated in following the planning game and they still have this planning game in mind years after finishing their studies.

Playing the game with professionals the chance is given to reflect on existing knowledge and experience. The participants can apply some ideas they were not able to use before in reality. Besides the theoretical content, all participants learn in some hours how to handle and run a simulation tool. During the redesign module, the participants are able to apply this new knowledge in about half a day for designing a probably fully new production system. After one day they are already able to run their new and own designed production system on the PC. Very often, this rapid realization period is surprising to professionals who are not usually using simulation tools.

7 OVERALL EXPERIENCES IN RUNNING THE DIFFERENT MODULES

As described in the previous chapters the seminar is composed of three modules with a preferred sequence. But due to its modularity the single parts of the seminar can be selected and used as stand-alone modules depending on the target group and the objectives of the seminar. Therefore, the introduction of the bicycle assembly presented in the production planning and control part has to be moved to the chosen module. Furthermore, the span of the theoretical lecture can be easily adapted to the initial skills of the participants.

Playing the seminar with students and professionals time restriction is another major criteria. Mainly small and medium sized companies are not able to leave their employees for a whole week of continuing studies because of daily work. Besides this, leaving a larger group of experts for several days is of major importance for the management. Therefore, single modules of the seminar can be organized starting with approximately two days for the production planning and control module or the redesign module. The duration can be enlarged by extending each module and combining it with the other segments up to five or six days. This duration usually fits to compact lectures at universities.

During the planning game itself, the participants are fully free to apply any support they have at their disposal. Therefore, spreadsheet software is very often used to fulfill the planning and reengineering tasks. In order to perform all tasks during the limited time of each module the teams have to organize themselves by splitting the work within the team. Furtheron, playing the seminar with a few teams in parallel, the speed in operating planning tasks is usually different which means a difference of sometimes one hour. The lecturer has to manage this problem with additional tasks to the faster planning teams in order to balance the speed of the groups.

8 SUMMARY

During the planning game the teams are learning very fast how to apply the simulation program as an adequate tool for analyzing and redesigning existing production systems. Following the seminar the participants are gaining an impression of how simulation can be utilized for operative and strategic investigations of own practical problems. The span of these problems is covering different planning and control strategies as well as organizational changes to group work or segmented work structures.

The actual configuration of the simulation aided planning game is resulting from the experience in running it over some years. The three different modules have been established as an ideal composition to enhance the awareness of real problems in the area of production planning and control, production controlling and redesigning existing systems. Additionally, participants are instructed in using simulation tools as an appropriate analysis tool in business process reengineering.

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10 BIOGRAPHY

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Implementing Process-Oriented Supply-Chains in a Logistics Game

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Abstract

This paper describes experiences with the use of a production simulation game as part of the course “Logistics and Operational Management” at the Swiss Federal Institute of Technology (ETH) Zürich. After a short introduction to the context in which the game is used and a description of the game itself, the results are presented and discussed. Even though the students have a similar background when starting the game, the results are very different. In the final section, the results and actions taken by the players during the game are interpreted from a logistics point of view. A consequent process organization was not implemented by any of the groups. Still, very interesting and good improvements have been achieved.

Keywords

Process organization, logistics games, supply chain management experiences with students

1 CONTEXT AND USE OF THE GAME

The Institute of Industrial Engineering and Management (BWI), part of the department of Industrial Management and Manufacturing Engineering at the Swiss Federal Institute of Technology ETH Zürich, is an industry-oriented academic institute. The research group of Prof. Dr. Paul Schönsleben covers the areas of Logistics, Production Planning and Control, Information Management and Total Quality Management. The vast majority of research projects in the research group are performed in collaboration with the industry. Many of these projects deal with the improvements of logistics processes within and between industrial companies.

On the other hand, the above mentioned topics are also covered in courses offered for ETH students. About half of the students are full-time students. They study two years in one of the engineering departments (Mechanical, Chemical, Computer or Electrical Engineering) before they join the Department of Industrial Management and Manufacturing Engineering. 3 ½ years later (including 1 ½ years in industry) they will receive their Masters degree. The other students are part-time students and have already achieved a masters degree at the ETH. They have usually also spent some years in industry. They receive their second degree after two years of part-time studies (including ½ year in industry).

The two semester course “Logistics and Operational Management” is the core of the teaching activities in the field of production management and is required for all students. Its main objective is to teach how to optimize logistics processes with the help of a process oriented systemic approach. It covers all subjects of production management from the design of process organizations and customer demand prediction to Just-in-Time principles and multiple-variant manufacturing issues (Schönsleben, 1997).

Since 1993, the Logistics game is played as part of the course in the very first lecture. It is very important, that, at this point of their studies, the students have almost no prior knowledge learned at university level on the subject of logistics. Of course, part-time students in particular but also some of the full-time students have work experience through earlier jobs or internships. Still, a structured introduction to this subject has been given to only few of them. The great advantage of playing this game before learning the background is to have students that are unprejudiced and more imaginative with the subject. They don't stick to principles that they have learned but rather try using common sense to find new solutions to the given problem. Still, as it will be described later, there is a difference in the results of students with and without prior industry experience.

Besides being part of the “Logistics and operational Management” course, the game has also been used for training in workshops of industry projects to promote process orientation and process thinking. Even though it is a manufacturing simulation game, the game was very welcomed and introduced fruitful discussions in projects with service sector companies as well.

2 THE GAME

2.1 Game structure

The game simulates the production process in a mass production manufacturing company producing only one product. The initial layout of the factory is shown in Figure 1. Four workers are needed to assemble the product. Every worker has his own table with a storage for incoming parts or modules, a storage for outgoing modules, and working instructions on how to perform his work. The product is made out of toy bricks which can be stuck together in different ways. After the final assembly, the product is transported to the quality control. In the case of possible mistakes, the product is handed over to the reworking which has to correct the production errors and eventually needs to rebuild parts or the complete product. If the quality control is satisfied, the product is moved to the finished products stock. The shipping department is then responsible for fulfilling the customer orders and sending the products to the customer through the external carrier.

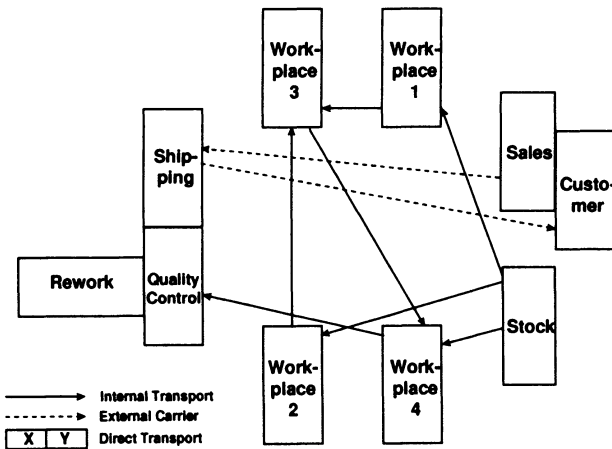


Figure 1: Initial layout of the production

The contact to the customer is maintained only through the sales person which receives the orders directly from the customer, and by the external carrier that delivers the ordered products. The external carrier is also responsible for all transports of order forms from the sales person to the shipping department. All transports of parts, modules and final products from the stock via the workplace to the shipping department are performed by the internal transport service. The number of employees that are directly involved in the production and order processing process, adds up to 12: four workers, one quality controller, one reworker, one sales person, one shipping responsible, one stock manager, two internal transport persons, and one external carrier.

Besides these employees there are two non-productive persons involved to observe the manufacturing process and work out suggestions for improvements: the general manager and the production engineer.

The moderator of the game play the role of the customer. In regular intervals, a (from the production company point of view) unpredictable number of products is ordered. The delivered products have to be checked on their correctness by the customer. Falsely assembled products are eventually rejected or rather reordered. The initial process structure of the production and the order processing is shown in Figure 2.

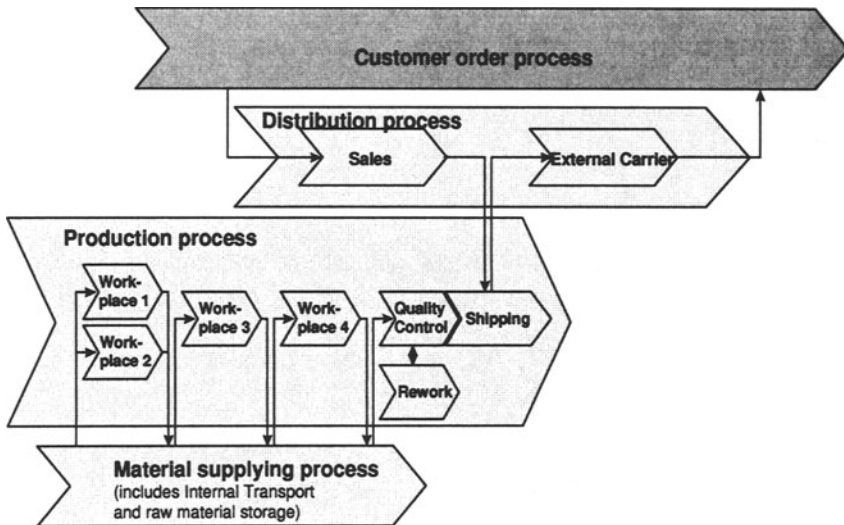


Figure 2: Initial Process structure of the production and the order processing

The production structure at the beginning of the game shows a very old-fashioned, Tayloristic production scheme. The customer contact is only used for determining the necessary quantity of orders to be shipped. Customer information does not provide any input to the production planning process itself. This push system produces independently of customer orders and the final products stock inventory level. This situation is worsened by an unorganized layout and batch sizes that are not harmonized between the work places. It is assumed that very specialized workers perform the given tasks. They only have instructions to perform their own work. Mistakes can only be corrected by the reworking. Communication between the workers is kept at a minimum. Only the communication between the workers and the internal transport service is allowed.

2.2 Playing the game

The game simulates the production over four to six years, where every year is simulated in one game period. In every game period, a number of orders are passed from the customer to the sales person in one minute intervals (one month intervals of simulation time). The number of ordered products varies and is usually kept quite low in the first game period to allow the production to start up. Products have to be delivered after 30 seconds. Late shipments are not accepted. Products are then checked on their correctness. The difference between the number of ordered products and the number of good products is added to the next order.

After ten to twelve orders, the production is stopped and the present state of the product is evaluated. Several factors contribute to the performance measurement. The values are determined and then transformed into cost such that an average price per product can be calculated. The factors can be divided into those that are almost constant over the game period and therefore independent of the number of ordered products in a given game period (and of the number of orders) and those that are related to the number of ordered products. The former consists of personnel cost (100 Units per productive worker, where the General Manager and the Production Engineer are not counted as productive personnel), and the cost for the storage of parts (5 Units), modules (20 Units) and finished products (50 Units). The variable cost describe quality and delivery ability aspects. Each incorrect product is counted with 100 Units and 50 Units are charged per product and period of late deliveries.

After the evaluation the group of students will get together and discuss their experiences of the last game period. The general manager moderates this discussion. The goal of the workshop is to find weak points in the production process and measures for improving those. These actions can range from changing the batch size or the layout to dismissing employees or introducing new organizational concepts such as group work. The group does not have a catalog of possible actions; they are almost absolutely free in what they may change. The only things that may not be changed are the product itself, the market structure (introducing more customers), and decisions on whether or not to source out parts of the production. In addition, due to a limited budget for restructuring measures, they are allowed to implement only two measures after each game period.

3 RESULTS OF SELECTED GROUPS

In this section, the results of some groups are described and compared. Results of both, full-time and part-time student groups are shown. About eight groups play the game every year within the course “Logistics and Operational Management”. Three groups of the past two years are analyzed thoroughly in the next sections.

3.1 Final Layouts and final process structures

The production site layout at the end of the game varied greatly between the different groups. Some groups reorganized almost every part of the production while others only changed details of the layout. Figure 3 shows the initial layout (as in Figure 1) and the final layouts of the three groups that are further analyzed in this section. Again, dotted lines represent transports by the external carrier while full lines show transports of the internal transport service.

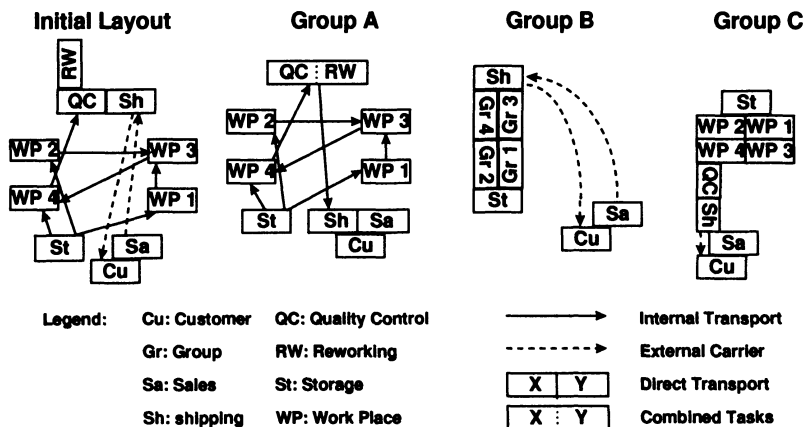


Figure 3: Layouts of the initial situation and final layouts of three selected groups

The initial situation is quite complex (see Figure 3, Initial Layout) and not oriented towards the customer. Some of the groups realize this problem and are willing to radically change the layout and the processes and to fully adjust to a customer-focused production scheme (see Figure 3, Group C). As a consequence, the position all working places are restructured and the stock is decentralized such that every worker has a stock of the parts the he needs for performing his task. It further implies that instead of using an internal transport service, the modules have to be passed on directly to the next worker in the production process. About one quarter of the examined groups made this radical move. Most other groups tried to find some kind of a middle course. Group B, for example, developed a layout in a U-Structure. Still, one has to consider that the groups have much freedom on which

measures and changes they want to implement. Only in few cases, the ideas of planned changes go beyond what is allowed. Some groups perform only marginal changes in their layout and production process throughout the whole game. The material flow in Group A is almost similar to the original situation. Only the quality control and the external carrier service were locally optimized.

Usually, the process structure is optimized by the groups during the game. The most important step in this context is the elimination of the internal transports. The modules and final products are moved from one work place to the other directly. Also the transport from the stock to the work places is often removed by introducing decentralized raw material stocks at every working place. The employees that used to do the transport jobs are either retrained to help out in bottleneck tasks or dismissed. It is interesting that the function of the sales person, whose job it is just to receive the customer order and to transmit it to the shipping department, is never questioned. The customer could send his orders directly to the shipping department and the sales position would become obsolete. Very often, steps are taken to improve the communication between the workers and to enhance the information flow as a precondition to a better production planning. But even if communication improvement is not taken as one of the measures, the communication between the workers and between workers and other members of the production team changes during the game. The discussion between the first and the second period usually brings up the question on how to better coordinate the group activities. Such discussions increase the sensibility towards certain issues and thus change the behavior of the workers.

One crucial aspect is recognized only rarely: The initial production process is an instantiation of the push-principle. Products are manufactured without really knowing how many products the customer will finally order. Only few groups realize that by introducing a demand-oriented, flexible production they can fulfill the customer orders exactly without high amounts of work in process and an overloaded finished products storage. Of course, this requires a relatively short production cycle time (Just In Time production), but usually in the second or third game period the production is good enough to handle this task.

3.2 Measures implemented by the groups

At the end of every game period, an evaluation of the present production situation is done as described in section 2.2 and decisions about changes are made. Figure 4 shows a statistic of the measures taken and the percentage of groups that implemented these measures.

Even though only little was known on the subject of logistics all but one group harmonized the production by introducing a unified batch size of 1. This step is implemented much easier in a game environment than in a real manufacturing process but it shows that the underlying idea of having small and flexible batch sizes is understood quickly. More than 85% of the groups also changed the

production layout to improve the material flow. Considering the complex and non-transparent original layout, this is not surprising.

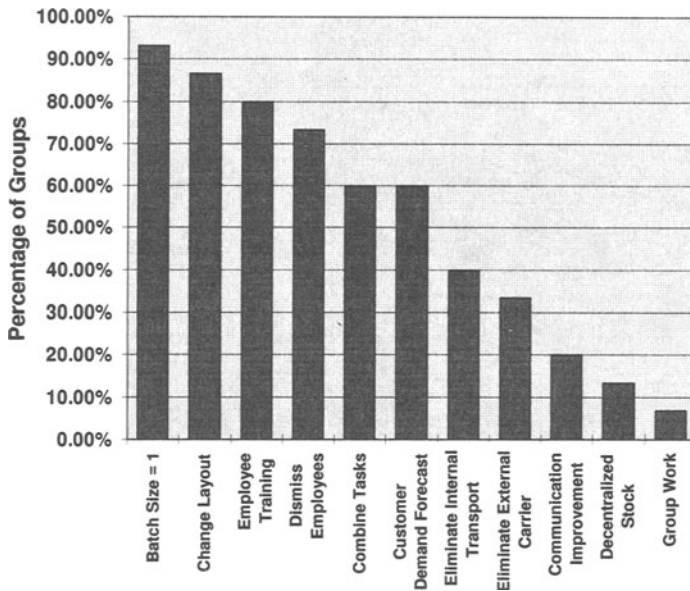


Figure 4: Percentage of Groups implementing measures (over 15 games)

Other measures that are introduced by the majority of the groups are part of the personnel management. Due to severe quality problems in the beginning, much effort is spent in training of employees either to do their job better, to learn new tasks that are performed in addition to their prior work, or to learn new jobs, f.e. to help out at bottleneck tasks. Usually, the learning curve, the experience and the production speed grows so fast that after the second round employees are rather dismissed than retrained for new positions (except for the learning of jobs of dismissed personnel).

A measure that is not directly an optimization of internal processes is the request for customer forecasts for future demands. With every order, the customer will also tell the probable order size for the next period, which can be up to 20% off the exact value. About two thirds of the groups figured that only an internal optimization is not enough to reduce the work in process. Additional information from the customer was needed to improve production planning and delivery flexibility.

Only in remarkably few cases, totally new organizational concepts as team work are tried. Usually, the material flow is optimized, some task are combined or eliminated, or the stock is decentralized. The strong division of labor in the

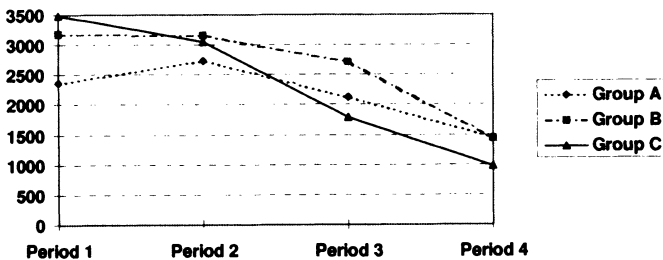
production is still maintained. Still, many of the major problems are realized and attacked by the various measures which becomes obvious in the comparing performance evaluation done in the following section.

3.3 Development of performance measurement figures

Measuring the performance is done by evaluating certain factors as already described in section 2.2. This allows to map the successes of the measures taken over the game periods and also is an instrument for comparing the different groups. The fix cost cover personnel cost and costs of the work in process which are almost constant over the game period. Variable cost cover costs emerging from incorrectly assembled products and late deliveries which are averaged over the number of ordered products. The following Figure 5 shows that, in general, a strong decrease of cost is achieved by all groups.

Usually, the variable costs are very high in the beginning. For Group B, the variable costs amounts to almost 90% of the total cost in the first period. These high costs result from severe quality problems and difficulties mastering the production cycle time. Therefore, training measures and quality discussions are among the first taken by almost every group after the first period.

Fix Cost (independent of the ordered quantity)



Variable Cost (related to the ordered quantity)

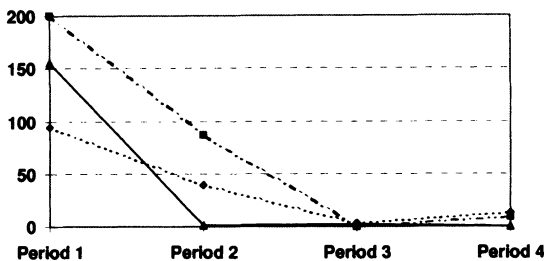


Figure 5: Performance development of selected groups

After the second round, the variable costs decrease enormously, which is partly due to the measures taken but also a result of the growing experience and comfort with the product and the game. As soon as the quality and delivery problems are almost solved, the groups realize that they have a huge amount of fix costs that is mainly caused by an inefficient material flow. Usually, these problems are attacked starting after the second period but smaller reductions are realized until the end of the game. In contrary to quality problems where the measures to be taken are quite obvious, it is difficult for the students to find ways to reduce the work in process, the finished products stock, and the personnel cost effectively. Group A, as an example, reduced the batch size to 1 after the first period (see Table 1). Still, the fix costs did not decrease but increased. In the given case, the better production and the reduced cycle time filled the finished products stock even faster. The change of the batch size cannot be taken as a stand alone measure but must go along with a change in the production control, as, for instance, a demand-oriented production scheme.

Table 1: Measures implemented by three selected groups

Measures Taken (selection)	Group A	Group B	Group C
Batch Size = 1	Period 1	Period 3	Period 1
Change Layout		Period 2	Period 1 and 2
Employee Training		Period 1	
Dismiss Employees		Period 3 (4 Emp.)	Period 2 (3 Emp.) and 3 (2 Emp.)
Combine Tasks	Period 1, 2, and 3	Period 2	Period 3
Customer Demand Forecast			
Eliminate Internal Transport		Period 2	Period 3
Eliminate External Carrier	Period 3		
Communication Improvement			
Decentralized Stock			
Team Work		Period 3	
Fix Cost in last Period	1450	1445	975
Variable Cost per Product	13	9	0
Average Cost per Product	26	27	12
Productive Employees	12	12	7
Production Cycle Time	60 sec.	50 sec.	47 sec.

4 INTERPRETATION OF RESULTS FROM A THEORETICAL POINT OF VIEW

4.1 Organization aspects

The Logistics Game is supposed to give to the students an overview over organizational aspects in production. The initial situation is characterized by a functional organization structure (see Section 2.1), as it is still wide spread in industry. Since the beginning of the industrial revolution this has been the dominating organization scheme. Many Small and Medium-size Enterprises use this approach until today (Frese, p. 337). While playing the game, the students learn about possibilities of organizational restructuring and get to know demands for modern organizations.

Table 2 compares functional and process-oriented organizations.

Table 2: Comparison of functional and process oriented organizations (see Osterloh, p. 24)

Functional Organization	Process Oriented Organization
high division of labor	job enlargement
many hierarchy levels	lean structures
many specialized jobs	holistic, customer-oriented tasks
stable, predictable environment	dynamic, complex, competitive environment

One organizational approach that was introduced by Group B as an experiment is the implementation of team work. This concept is implemented in a growing number of enterprises (Ulich, p. 171). Group B consisted mainly of part-time students with prior work experience which wanted to examine the effects of team work in a test case. Many of them never had the chance to experiment with team work in a production task before.

The semi-autonomous teams that were formed in the given case each performed all tasks that were necessary to build the full product. This included not only the work of the original work places one to four but also the quality check as part of the production. It was understood that if every team itself is responsible for the quality of its work, there is no need for a quality control any longer. The shipping accepted the customer orders and distributed the work among the teams. Depending on the size of the order and the working speed and capacity of the respective team they received a below or above average work load. The performance figures (see Figure 5) indicate that a high effort is to be put into training of employees when introducing team work. The product quality decreased in the last period which resulted in higher variable cost.

4.2 Process design issues

Major improvements to the production process are not possible if only the layout structure is considered in the analysis. The great potential for radical improvements can only be utilized by combining layout issues with a thorough analysis and optimization of the elementary processes. The reengineering approach as described in Hammer and Champy (p. 32) is a critical aspect. The task is not only to reorganize and restructure the processes but to question the need of every single elementary process and to define its significance and contribution to an added customer value of the product. Figure 6 shows a vision of an optimized, customer-focused production process.

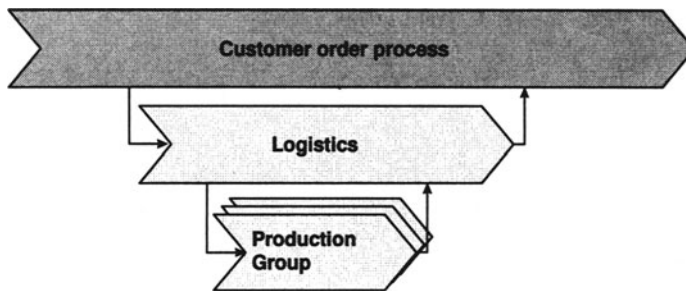


Figure 6: Vision of a process map

Compared to Figure 2, there is now a clear initiation of the logistics process through the customer. No longer will the production produce as much as it thinks the customer will order. Rather, the production speed is a result of the customer orders. It can be seen further that the logistics process receives much importance since this process includes the full control of the production. This aspect of reorganization can be observed in many enterprises today. The position of a supply chain manager who is part of the company management is becoming more common in customer focused companies.

In the example presented in Figure 6 the logistics team is now responsible not only for the material flow but also for the order processing, long and medium term production planning, the distribution of customer orders to the different production teams, and the coordination of the shipping. It is the only point of contact for the customer. The production team uses a decentralized stock and fulfills all tasks including getting the material and the production itself which embeds the quality control. The sales person is no longer needed since the customer corresponds directly with the logistics team. These processes show a very lean organization structure. The production speed is easily scaleable since from the organizational point of view, the number of production teams is not important. They could be added or removed according to long term demand prognoses.

In order to better demonstrate the improvements in the process design, it is the task of the production engineer to keep track of process changes using a process modeling methodology. Since the students have only little experience with using these methodologies, the optimization of processes with this tool were only partially successful. The ideal case of a process map as displayed in Figure 6 is usually not attained. Still, the process modeling helps to promote a new approach for handling reorganizations and developing leaner and less complex organizations.

5 CONCLUSIONS

Learning through games has a great impact on the students. Every group performed successful organizational changes to the initial production structure even though the results were very different. The logistics game teaches not only the possible options that may or may not work in certain situations and gives instant feedback since results of the actions are seen immediately. It also gives a practical introduction into process organization and layout optimization and helps to understand how reorganization can be started and put into practice.

From the teaching point of view, it is important to use easy ways to teach a methodology of process optimization (Hafen and Brütsch). Unfortunately, due to time constraints usually no more than four periods can be played. And there are so many other things to optimize...

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“There is more than one way“ - a game about production and working environment

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Abstract

The engineering education shall qualify the students to take considerations of the working environment into their solutions of technical problems. Especially learning about the consequences of the organisational planning and socio-psychological influences seems to be theoretical and abstract for the students. In order to make use of alternative learning theories a simulation game is developed to give the students an opportunity of experiencing a situation close to reality and yet being able to include reflective loops, breaks, to ensure a thorough understanding of The Developmental Work.

Keywords

Simulation game, Tayloristic work, The Developmental Work, learning theories, reflection loops.

1 INTRODUCTION

The purpose of this paper is to present the aim and principles in a generic educational game with focus on both educational problems and pedagogical methods. The game is about production planning and working environment.

The conditions for traditional working environment courses at the engineering studies leave little possibility of using the recent theories about learning in action, situated learning, reflection in action, and reflection on action. The courses are too short, and some of the subjects, eg social- and psychological working environmental elements, are rather abstract in a technical and rational field. By the use of games it is possible to simulate an adequate part of reality to establish a learning situation which creates opportunity for learning in action as well as for reflection in action and reflection on action. In this way, insight and awareness about physical, social and psychological working environmental elements in the production should be provided.

The following describes the background of the game, the learning approach and the content of the game. Finally we discuss the use of reflection and possibilities and concerns using a game.

2 BACKGROUND

During the past 10 years the unions and the working environment experts have become increasingly engaged in the concept of "The Developmental Work". The Developmental Work is a production concept introduced by the Swedish Metal Workers' Union in the mid-1980s. It describes a new strategy for the trade unions' focusing on what they see as current possibilities of establishing consensus between the workers and the employers on development of work, flexibility, quality, qualifications, etc. - possibilities related to the new market conditions. Job enrichment and highly skilled workers to secure flexibility, involvement of employees in decision making and planning of work to increase motivation and quality, and employee influence on product and services are some of the potentials outlined (Hvid & Möller 1992).

In Denmark there is a general and increasing understanding of finding alternatives to Taylorized work. This has lately been expressed in the action programme for minimizing repetitive, monotonous work drawn up by the Danish Parliament (Busk Kofoed and Garsdal 1993). At the same time the companies have an increasing understanding of the necessity of a good working environment because of the above mentioned conditions (Andersen 1992). But still we see many and even new companies with repetitive, monotonous work based on Taylor's principles.

When new products, and therefore new production planning, are introduced designers and production engineers have great influence on the working environment (Broberg et al. 1997). Therefore the knowledge and consciousness of the working environment's importance for the health and developmental potentials of the employees as for the general capability of the companies is of great importance in the engineering curriculum. The knowledge that newly qualified

engineers have developed during their education, is crucial to the working environment in the companies (Tybjerg Aldrich 1994).

2.1 Engineering students' approach to production planning and working environment

When engineering students are admitted to the study, they often have an idea of engineering as an isolated technical development and production in which they find it rather difficult to plan with perspectives from The Developmental Work in the design and planning task. Most of the students can see the possibilities and the advantages of establishing a good working environment in the company. They also consider the necessity of making a reliable, economical production plan. The problem is to integrate working environment and production planning.

During the production planning courses the different levels of a product's working up will automatically mean that the flow of the processing has to be broken up into a number of single elements. When planning the production flow it is of course important to know and understand how to handle the specific operations to be able to plan for machinery, tools, manning, cycle times, etc. In a theoretical planning approach a production will look profitable when it is planned from a technical and rational point of view with focus on all segregated machines, processes and functions. It is our experience that this necessary fragmentation affects the work organization and thereby the social and psychological elements when the manning is planned. Those elements (the "irrational" elements) which we by experience know are important for lead time, quality, time of delivery etc. and thereby for the profitability are often underestimated or non-existent in the production plan. This gives a wrong impression of e.g. the possibilities concerning employee motivation, responsibility for quality, and the ability for employee interventions in unexpected situations.

The students are inclined to man the production corresponding to the stages in the machining, for instance in the assembling: "one man one task". This means that the work organization is based on the different levels of processing rather than on the elements which altogether create developing and qualifying working conditions for the employees. The students often end up with a production plan which, so to speak, programmes repetitive, monotonous work.

The challenge therefore is to design a simulation game that illustrates the consequences of fragmentation and a too narrow focus on the manufacturing operations versus the possibilities of an integration of working environmental aspects in the production planning. The purpose of the game is to show that production can be planned in several ways, one of which is to integrate the working environment and with aspects from The Developmental Work: production process planning with an anthropocentric approach.

2.2 A simulation game with an anthropocentric approach

The game is based on a case that describes a company situation and the product. The game is designed to have two scenarios. One in which the game is played with

a production sequence based on a Taylorized production planning, and one scenario based on an organization containing elements from The Developmental Work.

By using two scenarios, awareness should be established about the different focuses in production planning and the different consequences for the working environment. Furthermore, the two scenarios should lead to a discussion of important aspects of establishing and developing a good working environment and the benefits for the productivity.

The game process in the two scenarios can widen or reduce the scope of actions, because the players are not given any personal instructions connected to the role. The role is only presented as that of an operator and a task to be fulfilled.

During the game process it should be possible for the game leader to make interventions, either by adding some unforeseen situations to the game or to stop the game because a specific situation needs reflection.

3 THE LEARNING APPROACH

The learning approach has to fill out the gap between the abstract working environmental aspects and the more concrete subjects about production planning which the students have to work with. The approach is based on Kolb's learning cycle. (Kolb 1984). Kolb's learning cycle shows that learning, especially the type of learning which is required in relation to non-technical working environmental issues, takes place through a series of phases in a cyclic process which can be described as:

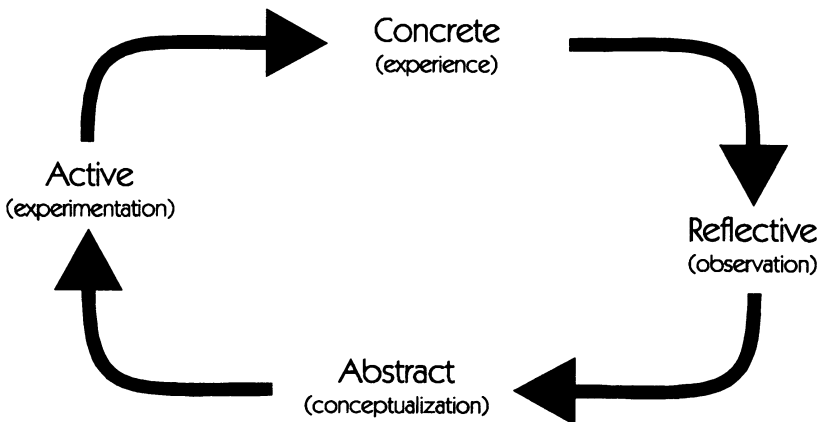


Figure 1. Kolb's learning cycle encompasses two significant areas: one which covers action to reflection and one which covers the transition from concrete to the abstract.

Kolb is talking about problem-solving as problem-oriented learning, where the problem represents both the motive and the content in the learning model. When

the context of learning is technical issues in relation to better working environmental performance, Kolb's learning theory is relevant, as problems often are the background for the necessary learning, and additionally his learning concept is based on 'learning by experience' and 'learning by doing'.

For many years John Cowan has worked with the significance of reflection in relation to learning especially when and how in the course of the learning process the reflection is placed and performed. Cowan's concept of learning is based on how learning based on experience takes place, and especially how learning is performed together with others in a group (Cowan 1996). Cowan in this way introduces an approach to the collective aspects in the learning concept, and he modifies the Kolb cycle to encompass the following words as illustrated in figure 2.

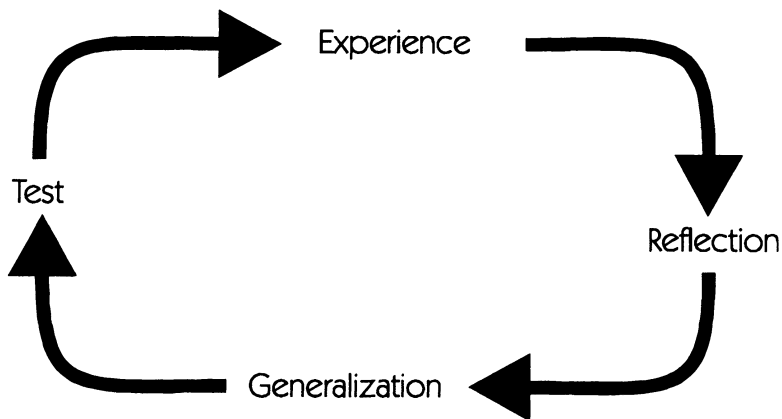


Figure 2. The Kolb cycle with words paraphrased by Cowan. (Cowan 1996 p. 32)

The words in Cowan's Kolb cycle are discussed in the following.

Experience: As a basic approach one can say - in the context of a specific learning process - that all participants have their own individual experiences. The participants' experiences in a learning process may be categorized into three types. Among these experiences some are more interrelated than others.

One type is experiences which are shared by everybody participating in the learning process. This experience is often to a great extent concordant for all students in the group. Such experiences may typically be the function and the structure of the university's management, the social structure in the university, and the culture of the university. These experiences are fundamental to the common language and understanding in the group of learners in the initial period of the learning process.

Another type of experiences is based in the individuals' daily working situation and problem-solving methods. These experiences may be shared by some in the

group, but not by all. This type of experience may contribute to a specialist in-put into the learning process from individual participants.

A third type of experience is external input from others such as lecturers, other students, etc. In this way the participants in a learning process have access to an infinite number of experiences, a fact to remember and consider when planning a learning process.

Reflection is by Cowan considered the central issue in the learning process, and this is why he describes his learning concept as 'reflective learning'. A distinction between three possibilities for reflection may add valuable understanding to the concept of reflection. Cowan indicates that Schön (1987) distinguishes between reflection related to action and reflection related to experience, called reflection-in-action and reflection-on-action. These types of reflection are mostly retrospective in their attempt to make an analysis with the purpose of using the results in future learning situations. Cowan therefore add a third learning distinction which is reflection-for-action, in which the participants reflect upon which types of problems they hope to be able to solve more successfully in the future than they have been and are at present. Reflection-for-action is described like this:

"It is a reflection which directs subsequent learning by identifying needs, aspirations and objectives which are then kept almost constantly in mind". (Cowan 1996 p.37)

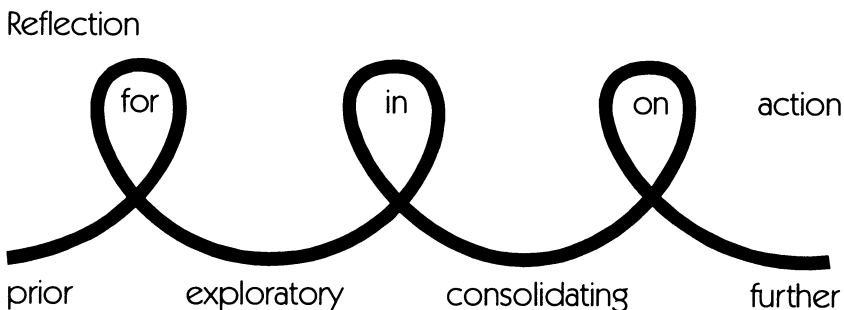


Figure 3 illustrates the process with three reflection loops: reflection for, in and on action.

By reflection-for-action it is understood that in the first stage of the learning process it is considered and rendered visible why the learning process must be performed, what it shall contain, and how it is to be carried out and evaluated.

In order to ensure, that the learning process is 'on track', a planned reflection (reflection-in-action) is included in the process. During this reflection it is contemplated whether or not you as a teacher or a student are working in the right

direction and whether or not the thoughts, scope and goals for the learning process you made in the first place are still valid or if it is necessary to revise and adjust the planned process. Furthermore the preliminary outcome is considered and afterwards what you want the students to learn later on in the process. After the learning process has finished another reflection loop, reflection-on-action is instigated. In the reflection-on-action phase you consider what has been learned, why the outcome of the learning process turned out as it did, and how the outcome may be applied in the future.

Generalization and test. After the reflection loop is finished the results of the reflection are generalized, and based on the generalization a test is planned with the aim to verify or falsify the generalized results, or to build on/challenge them.

The Cowan diagram as showed in figure 2 is a simplified representation of what happens in real life, and a complete round in the Kolb cycle is not always made in the learning process. In real life, Cowan states, you may begin with experience - reflect on the experience and make a part-generalization to which you add another related and relevant experience - reflect on this, make another part generalization and so on until you add the part generalizations to an aggregate generalization, which is subsequently tested.

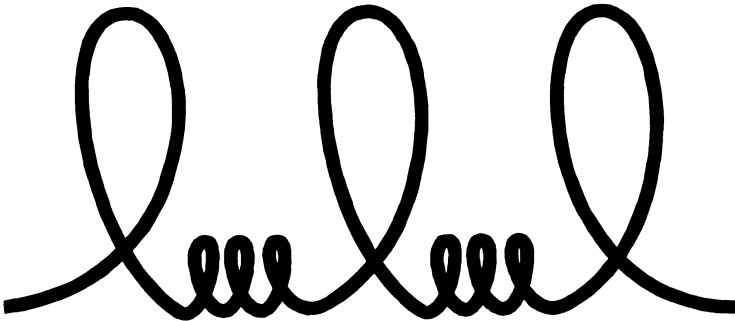


Figure 4 shows the modified Cowan Diagram.

The Modified Cowan Diagram illustrates that a series of minor reflection loops are made between the three planned reflection loops (reflection-for, reflection-in and reflection-on cf. figure 3). These small reflection loops are attached to the 'here and now' learning situation. The small reflection loops are typically without test, as described above, while the 'big' reflection loops represent complete learning cycles cf. figure 1.

The ideas in reflective learning seem to present an operational approach to obtain objectives and goals set for the learning process. Goals and objectives are

necessary in connection with common learning processes of the type suitable for our purpose, as it is the periods of reflection which particularly contribute to the depth and durability of the learning within the cognitive as well as the affective area.

The ideas of reflections support the pedagogical goals in the game. The game has to create awareness about different approaches of production planning, and to illustrate working environmental aspects of the production as well.

4 DESCRIPTION OF THE SIMULATION GAME

The game simulates two production situations to be played successively during two scenarios in a plant, LUDO A/S.

Scenario 1: A line production indicating repetitive, monotonous work.

Scenario 2: A production where the group organizes their own work.

The production is a fully documented production of a windwheel. Documentation is made according to the quality management standards.

The product, a windwheel folded in paper, is chosen from several criteria: cheap raw materials (paper, wooden pins, distance sleeves and needles), few auxiliaries, the possibility of Taylorized production, only a little training required.

Total playing time is four hours.

4.1 Scenario 1

The participants are divided into two groups, one group of 7 members participates in the game, and one group that observes the game. If possible we form two groups of players and two groups of observers.

Scenario 1 is organized with a very strict Taylorized organisation with no initiative left to the workers.

A foreman and a floor man (serviceman for filling in materials, relief, etc.) are appointed in the team. Five members are blue collar workers.

The game leaders arrange the layout of the plant beforehand. Five tables are placed on a line with some space between them in order to illustrate an assembly line where it is impossible for the workers to communicate. The foreman's table is placed at some distance from the line, and so is the floor man's a table for the storage from which he fills in for the production line at the tables.

The production is divided into 5 operations followed by very detailed work instructions. The game leaders deliver the documentation to the groups. A description of the plant, the product and the production system is distributed to the team. The documentation of the production is delivered to the foreman ie part lists, layout, work instructions, production orders, sales orders, etc. Instructions for evaluation are distributed to the observers.

All the participants are informed about the company situation and the product. While the foreman is reading the instructions, the game leaders practise folding of

the windwheel with the workers to ensure that the production is running at full speed from the first batch.

The production chart is based on the sales orders delivered from the game leaders. Around 6 sales orders (1 to 8 windwheels in each batch, 4 variants) make about 1 hour's production.

The production begins with a one piece batch to avoid too much spare time. After the first batch the team is on their own lead by their foreman according to the instructions.

4.2 Scenario 2

In scenario 2 the foreman is asked to join the observers. This leaves a team of 6 workers to produce the orders.

The team receives the documentation from the game leaders and they have 10 minutes of initial planning of layout and production.

In scenario 2 the new work instruction is describing a full production of a windwheel while the sales orders are the same as in scenario 1. The production order is prepared for the full production of a windwheel. Again the playing time (production time) is maximum 1 hour.

4.3 Game materials

All the documentation and materials for the game are gathered in two boxes to enable unexperienced game leaders to run the simulation game without help.

A script is explaining how the game can be carried out from beginning to end. An important point is, however, that the participants should be left to define their own personal roles.

A folder contains all the documentation for the production together with models of the product and various descriptions and instructions to be copied for the game. The content of the folder is:

- Case description of the plant and its situation on the market
- Sales orders
- Formula for production process planning
- Work instructions for all participants
- Quality control instructions
- Layout map
- Evaluation instruction for the observers
- Evaluation instruction for the players
- Script
- List of all the materials needed for the game

4.4 Two types of intervention in the game

To illustrate unforeseen events during the production, the game leaders intrude in the game.

Examples of interruptions can be: a telephone call for one of the workers, sick leave, lack of raw materials. The interruptions will illuminate the flexibility or lack of flexibility of the production system. The same interruptions are made in scenario 1 and 2.

During the game, interventions are made to facilitate reflections on the experiences. The interventions are sometimes planned beforehand and sometimes derive from the focus of the process of the game.

5 RUNNING THE PLAY

5.1 Running of scenario one

The game developed very differently due to at least two circumstances:

- different knowledge/background of the teams as to production process planning, and
- freedom to define the personal characters of the operators and foremen.

The teams' backgrounds seem to be very important for the outcome of the game. One team was studying production process planning, their production was running instantly in an efficient way with few delays but they obviously focused on quantity rather than quality. The team worked hard to minimize the lead time and this caused rejected products due to low product quality.

Another team was less familiar with production planning and consequently they had difficulties in getting the production started and with maintaining a balanced flow that kept all operators equally busy. As a consequence the operators had several boring delays.

We have consciously avoided to define the personal characters of the players in order to make the roles open for interpretation. This led to very different progresses of the game as the participants did not hesitate to give a personal interpretation of the roles, playing authoritarian, reluctant, helpless, etc.

During scenario 1 the repetitive, monotonous work very soon felt boring and the players began teasing each other or the foreman, making jokes and making errors on purpose. Thus the participants themselves experienced monotony. An authoritarian foreman typically provoked infantile or demotivated behaviour.

5.2 Running scenario 2

When scenario 2 was running, an interesting discussion took place in one group as to whether the group should have a leader or not. The members of the group disclosed very different attitudes to planning and implementation ranging from "let us make it perfect from the beginning" to "if it does not work we will just change it". The group ended up with an agreement that they would try to run the game collectively. As to the organisation of the production there was a discussion of how many operations each operator should take. The team agreed that each member should produce a complete product from bringing the raw materials, doing the

quality control to delivering the finished product to the storage. The team set up the layout so that everyone would be in contact with one another and so that everyone had access to the documentation and the sales orders. They distributed the first sales orders among the team members and the rest of the sales orders were left according to priority.

Before production start the team worked on how to make the product by helping one another.

Once the production was running it seemed to be very efficient. One of the game leaders' interruptions was to ask for a rush order and this was instantly taken care of. Each operator still produced a whole windmill and the whole batch was finished very quickly. Afterwards the ordinary batches were produced.

As the team members were in contact and could talk during the production they proposed improvements and rationalizations of the production methods during the play, improvements which could be implemented immediately.

Thus, to the satisfaction of the game leaders the team itself spontaneously demonstrated the advances of The Developmental Work.

6 DISCUSSION - LESSONS LEARNED

We would like to discuss the game at two levels:

discussion of the game

discussion of reflection

6.1 Discussion of the game

In the first scenario the simulation game is a good illustration of the limitations in a Tayloristic production - especially concerning flexibility. Another visible point is the amount of time wasted when a problem occurred on the assembly line, and the role of the foreman. If the foreman takes the role as dictator, the students who play operators respond negatively to his attitudes become demotivated, find excuses for leaving the workplace, cut their fingers, etc. An interesting thing was that no one was told to put any individual characteristics in their role, however, everyone shaped their role in a way which they presumed would fit the game situation, ie how they thought people with this kind of work conditions would behave.

In the second scenario no one put on a role except the one which was in the script. Everybody did their best to fulfill the tasks, and everybody used their experience about cooperation and group work. The production was a common responsibility.

We find that the simulation game is an effective participative learning method. All the students are actively involved in the game either as players or observers. The question is what the students learned. Based on the evaluation of the game we can say that the students are now aware of some consequences stemming from a Tayloristic and an anthropocentric production planning approach. Different approaches have different consequences for the working environment.

The game could be an excellent starting point for a discussion of The Developmental Work.

6.2 Discussion of reflections

It is very important but also very difficult to make reflections during the game. Many events which are very relevant for evaluation and dialogue take place during both scenarios. The wanted events obviously will take place but it is very important that the observers and the game leaders concentrate very hard on picking up things to be able to support the reflection that will lead to learning. The game leaders' awareness seems to be very important to make it possible for them to put facilitating questions for reflection instead of giving the solutions to the problems.

The game leaders have to take the time to facilitate learning when unforeseen episodes occur during the game, and to make the new knowledge "visible" so the students get the "oh" experience. Furthermore the observers' role should be emphasized, primarily because feed-back from "one of your own" is more powerful and secondly, because a seriously elaborated feed-back provides observers as well as players reflection and knowledge.

Interruptions during the game cause certain problems so that the game leaders must be aware of the balance between a spontaneous running of the game and the reflection as the base of a more long-termed intellectual learning. The spontaneous course of the game will give the students a possibility of feeling and experiencing a situation far from the conventional learning situation. The purpose is to give the students an impression as close as possible to the real working conditions and to make them feel on their own bodies what monotonous work is like. By combining an experience close to the "real life" and the intellectual reflection in the game, we intend to implement holistic learning. The task is to let the game run spontaneously and at the same time have creative reflections on what is going on and why things turn out the way they do.

When the students in scenario one show signs of boredom from doing repetitive monotonous work the game leaders might interrupt and put facilitating questions. The questions must not give the answers but should make the students think and put questions to themselves, like: "how come that operator 2 reacts to the foreman is this way?", "when did operator 4 start to tease the floor man?" and "when did the decrease in the product quality appear?"

In scenario 2, one of the participants suggests an improvement of the production process. The game leaders interrupt and facilitate a discussion of how the organization and layout influences the communication between the employees.

After the game the reflection should increase to a new level where the students reflect on what they learned from the game and what made them learn from the game. It is also essential to emphasize that the game should not illustrate results of the production e.g. different lead times and improvement of product quality. The point is to make the students see that there are other ways than Tayloristic production planning.

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Remodel, a game for strategic issues in industrial R&D and production planning

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Abstract

This chapter describes the game 'Remodel'. It has been developed in the Netherlands. It focuses on strategic decisions in regard to technological innovation and environmental regulation. The game stimulates the awareness of science and engineering students for the organisational and political context of their future professions.

Keywords

Games, Technological Innovation, Strategy, Environmental Policy

1 INTRODUCTION

The Dutch university system was reformed in the 1980s. The university curricula for science and engineering were reduced from about 5.5 years to 4 years. In this process, courses on philosophy, psychology and social sciences were often abolished. Key staff members generally supported these courses. However, their influence weakened in the universities that became increasingly market-oriented. As a result, reflective courses disappeared from the curriculum. Ever since, science and engineering students received very little training in how to deal with the political, economical, ethical and social/cultural aspects of their future professions. Although many employers of scientists and engineers had previously been rather sceptical of the critical content of "Science, Technology and Society" courses, they started realising that these courses had contributed to the scientists and engineers social understanding and social skills. As a result of the critique of employers, universities tended to give more attention these subjects in the 90s.

In 1991 Groningen University set up a course for undergraduate science students on 'Industrial Innovation and the Environment'. This course teaches the main environmental threats and the contribution of new technology to their mitigation. However, many barriers and risks of various kinds (economical, cultural, political, and organisational) have to be overcome in order to realise the potential environmental benefits of innovation. These issues cannot be dealt with just by lectures and the study of text books; bringing new technologies into being also involves persuading other people in order to get their support, being able to delegate problems, dealing with regulatory agencies, etc. In 1991-92, therefore, we developed the social simulation game Remodel to enable students to feel what it was all about. It was successfully used in the spring of 1992. Later, the game was also used for engineering students at Delft University of Technology, and environmental management students at Tilburg University.

At all three universities, Remodel is played at the end of theoretical courses that mainly focus on (industrial) technological innovation, environmental targets and constraints, environmental management and environmental policy. Thus the participants in the game have studied some theory and cases before. Remodel should contribute to their skills to apply that knowledge in practice.

2 THE REMODEL GAME

2.1 Basic Idea

The aim is to teach science students to recognise the social processes in technological development and to give them skills to deal with its non-technical and non-scientific elements. These subjects can be, and actually are, reflected in lectures on environmental, social, organisational, economical and policy issues in science and technology. However, we are convinced that students learn more when they not only learn to reproduce textbook wisdom, but really feel the tensions in actual innovations and the friction between self-interest, group interest and political convictions, economics and the environment, impartial administration and active

government interference. To have the participants really go through these conflicts, we decided not to develop a role-game (that is, a game played according to role prescriptions) but to develop a simulation game (that is, a game that creates a setting in which participants can develop their goals and roles in interaction). Van der Meer (1983) showed that, under the right circumstances, participants very rapidly create their own world within given institutional structures.

Once the game has started, the level of 'inclusion' of the participants, that is, the degree to which they actually act according to the norms and values of the institutional unit to which they belong during the game, rises very rapidly.

Remodel focuses on strategic decision-making regarding industrial production, technological innovation and global environmental issues. The main actors dealing with these issues are corporate executives, research managers and market analysts within industrial corporations, governmental agencies, environmentalists, the 'general public' (through the media) and eventually academic scientists and politicians. In order to achieve a dynamic game it is important that multiple relationships exist between these actors. If not, individual actors could easily decide just to make their own policy without paying attention to anybody else.

A carefully designed social structure of various 'checks and balances' therefore has to be designed to create a need for negotiations and compromises. In the context of a game, this system of 'checks and balances' is hard to achieve for those actors who are guided not primarily by economical incentives but by 'credibility', such as environmentalists and politicians. We therefore simplified the set of actor groups participating in the game:

Corporation

Executive Board

Department for Research & Development

Department for Marketing & Sales

(Supervisory Board)

Union Representative (=employee of Marketing & Sales)

Government

Environmental agency

(President)

Journalist

The game manager plays the role of President. The President is allowed to interfere when the environmental agency is totally overruled by the industrial lobbyists. Usually, the President is hardly active during the game. The Supervisory Board, also a role played by the game manager, has the same function. In general, it only plays a role in preventing an early bankruptcy. In that case, the game manager might let the corporation survive at a mere subsistence level. Each actor group (except for the journalist and the President) is made up of three or four individuals, each having a different position (chief, expert on...) within their group. At the same time some actors have specific positions, such as union representative.

2.2 Designing a social structure by the control of money and information

For a good game, a social structure is needed offering each participant at least a small chance of influencing the course of the game. Therefore, more than one kind of authority is necessary. We take money and information as basic elements to design the social structure of the game. Control of money can be used to build hierarchic positions, while control of information (by expert groups) or information flows (by the media) can be used to counteract hierarchic control. The game is designed to be played in annual cycles. At the end of the year the corporations make their decisions on investments, production, etc., based on government measures taken during the year. These decisions are fed into the computer, which calculates the corporations' financial results. The computer program simulates the ups and downs in the markets of the industrial products involved. The computer program only administers the game, and does not have a major influence on the course of affairs.

The length of the year is fixed at 40 minutes. This period is deliberately chosen to be rather short, as we want to ensure that no player ever feels superfluous. On the other hand, shortage of time forces the participants to depend on the judgements of others instead of working out everything for themselves. Moreover, some stress contributes to the realism of the game. The end of the game is always sooner than announced, as we want to prevent 'end of the world' effects, like spending all available money, making one last gamble that would bring the company enormous success, etc. In general, about 6-8 years are played. Practice has shown that this is generally enough to experience the processes for which the game is intended.

Money

Within the corporation the financial flows are controlled by the executive boards, and are therefore a means of maintaining hierarchic control. The treasurer of the executive board can draw money from the corporate bank account, which is kept by the computer program. This money can be used to pay wages. Each year the executive boards determine the wages. They receive a proposal for the wages in the first year of the game; in this proposal the lowest wages are about 25% of the highest wages.

The game money is of real importance. All participants have to pay for their lunch and drinks right from the start; that is, the corporation has to be profitable, otherwise the participants will 'starve'. In many cases, the executive boards pay bonuses during lunchtime. Of course, there has to be something worthwhile for participants to spend excess game money. In general we supply something expensive that becomes a status symbol. Sometimes, charity is introduced to pay for some participants' lunch. In practice, the game managers prevent participants having nothing to eat.

During the game's introduction participants often ask whether bribery is allowed. The game manager then answers, 'No, of course not, what else do you expect the President to answer?' So bribery can occur and it is often admitted afterwards that it has occurred, but on a very limited scale.

Information

Modern corporations are not (solely) controlled by hierarchic power based on the control of finance. Various groups within the corporation have a certain bargaining power because of their specific resources (specific expertise, relations, etc.). Since none of the participants in the game has specific expertise, the corporate hierarchy is balanced by a flow of specialised information from the computer towards the marketing and R&D departments. The result is that executives, marketers and researchers, who each have rather different orientations in evaluating corporate decisions (cf. the famous studies of Lawrence & Lorsch, 1967), have rather balanced bargaining positions in regard to corporate decision-making on the course of technological innovation.

Another important aspect of the game is the regulation of contacts. As the participants are often acquainted with each other, some rules must be maintained to protect the pre-given social structure from the effects of pre-existing social ties. If not, the participants are inclined to get together, discuss all matters, share all the information, and change the simulation into a game of 'all against the computer'. Hence three rules are strictly enforced:

- all communication between the various groups is in writing, and is transferred by mail system
- meetings are very limited and only possible with the approval of the game manager
- the simulation will not be paused once it has started; that is, lunch, coffee and tea are served at each group's quarters.

Naturally, larger meetings are not prohibited when they are really necessary in the course of the game, for example a strike meeting or an environmental conference.

Regulatory agency

The governmental agency's budget depends partly on the state of the economy. This means that it is a percentage of the corporate wages. The agency's regulatory power over industry is rather limited; only levies on production and a ban on the application of the industrial product in specific applications are allowed. Moreover, the agency has to announce all its measures at least six months in advance. It may withdraw the announced measures, but can never introduce measures that have not been announced. This means that the agency has only rude tools to steer this branch of industry. Moreover, it gets little information on the economic effects of its measures on the companies involved.

The early announcement of measures, and the lack of discrimination of these measures, implies that there is a strong incentive for the companies to negotiate and lobby. As a result, the agency is generally involved in many discussions with various parts of the corporations. Frequent topics of discussion are access to information and the effects of regulatory measures. Only on a few occasions does the simulation manager have to use his powers as President: either to enforce the agency to take action on the environmental issue, or to prevent it from shutting down this branch of industry right from the start. However, the agency often applies for a budget to subsidise research and development into new, clean products.

These budgets are generally granted on condition that the agency submits a detailed project description and proves that the subsidies are covered by the levies on the 'dirty' products.

2.3 Case

Environmental problem: CFCs - Ozone Hole

The global environmental dangers that threaten our civilisation (such as global warming, decreasing bio-diversity, depletion of non-renewable resources, long-term health and reproductive effects of newly released chemicals, and military-conflict-induced disasters) are also generally the ones that are rather controversial, especially in the initial stages when the issues are first discussed.

We estimated that the actor groups we have defined in the game would probably be inclined to refuse to take action without strong evidence. Pressure to change would then necessitate strong government action, which in turn would depend on strong public support. Since we decided to focus our game on the industrial rather than the public part of this process, we looked for a case with scope for debate between government and industry, but with little scope for industry to refuse to take any action. The CFC (Chlorinated Fluoro-Carbons)/Ozone problem was excellent for our purposes. Moreover, this case was very well documented from an industrial economy/business study's perspective, i.e. by Manzer (1990), Moore (1990), Smith (1989) and, most usefully for our purposes, Forest Reinhardt (1989).

The starting point of Remodel is the CFC industry in 1974, when Molina and Rowland (1974) published their famous article claiming that CFCs, after being released into the atmosphere, deplete the ozone layer. The ozone layer filters out harmful ultraviolet radiation, and therefore its depletion might cause a rise in skin cancer and lower crop growth. However, at the time that Molina and Rowland formulated this relationship between the release of CFCs and ozone depletion, no empirical evidence existed that ozone depletion was actually occurring. Because of the availability of Smith and Reinhardt's data on the US, we chose to simulate imaginary US corporations and the real US Environmental Protection Agency (EPA), though with imaginary powers.

Game decisions

The decisions that the corporations have to take within the course of a year are varied. They have to decide:

- the number of plants for each CFC they produce (each plant has a fixed capacity)
- the marketing budgets for each CFC (to increase market share)
- the price levels for each CFC they produce
- process research (bringing down production costs)
- investment in R&D projects for new products
- (if enough R&D is done) the introduction of a newly developed product onto the market
- salaries and the withdrawals from the company's bank account

For financial success it is crucial to have the plants run at (almost) maximum capacity. However, closing down plants as well as opening new ones is expensive, and it is therefore rather difficult to determine the right moment to adjust plant capacities. Conversion of a plant is possible and is cheaper than first closing it and later opening a new one. In fact, only the marketing department receives the information required to make these decisions. For the R&D department similar considerations hold as to whether or not to invest in a research project.

The EPA can influence prices and demands by means of levies and regulations. Levies can be varied and can even be negative (e.g. a subsidy). Levies cause markets to decline and prices to fall. However, their effect is moderate as compared to the bans on specific applications that can be introduced: for example a ban on CFCs in spray cans causes an almost complete collapse of market demands and prices. Thus it would mean the end of the game if this ban were implemented right from the start. However, by first introducing levies, and announcing its intentions several years before, the EPA can introduce such a ban without necessarily bankrupting the industry.

As stated above, we do not instruct the participants to achieve a pre-given goal. We therefore tell them not to 'replay' the history with hindsight, but to start dealing with the given situation of uncertainty. We could have dealt with this problem by making the game purely imaginary. However, this could mean that participants would experience the game as less realistic. Moreover, in practice it turns out that most of the participants only vaguely know the historical course of events, and are only aware of the serious character of the ozone/CFC issue.

In the course of the game we had to change the historic course of events a little. In practice we cannot play more than 10 'game years' in a one-day run, and it was therefore important to change the dates of some historic events (the discovery of the ozone hole above the Antarctic, the Montreal Protocol) to include them in the game.

Initially the game simulated the interplay of one industrial company and the EPA. Later we realised that the element of competition was missing. In the game this was a problem particularly for the EPA; if the agency wanted to pursue a more active policy to encourage the replacement of CFCs by non-harmful compounds, it was solely dependent on the co-operation of one company. This company therefore had a very strong (and unrealistic) bargaining position towards the EPA. The introduction of a second company also enlivened the game by provoking intercompany competition.

2.4 Practical arrangements

Computer use

A computer model simulates demands for various types of CFCs and market prices. The model is based on extrapolations of data contained in Reinhardt's (1989) study. These show that the Molina and Rowland article significantly affected the market positions of two major CFCs. The third one, CFC 113, was hardly affected by the news as this compound was mostly sold to industrial users, that is the microelectronics industry, which was growing fast.

The computer model uses several random factors. This is not just to make the program more realistic but also to avoid making the outcome of the game too easy to calculate. Since our participants are generally science or engineering students with great mathematical skills, we do not want them to try to calculate the algorithms of the software. All the same, one can observe a tendency among these students to try to beat the algorithms of the computer program. Random factors are therefore absolutely essential. However, as a consequence, the competition between the two CFC corporations is partially decided by chance.

In evaluating the game we use the computer program to show why loss of profit occurred, why companies have been financially successful and whether the government agency's policy has been successful, and we look at the environmental impact of all the actions. Often we observe that it is only at this stage that participants discover the logic of each other's actions.

Preparation for the game

Before the game each participant receives a general description of the game and of the actors who are included in it. Secondly, they also receive an information package describing the organisation or department in which they participate, and their main activities, and they receive some advice on the options open to them and the implications thereof. Each group has separate quarters, and they are urged to go there immediately after they receive their information packages. They study their information with colleagues and determine their strategy. Generally, Remodel really starts about 75 minutes after the start of the introduction.

Before playing the game many practicalities have to be arranged: nine more or less separate sets of quarters, coffee, lunches (and something 'expensive', like cakes), memos, decision and advice forms (to prevent people forgetting to deal with all the relevant issues), game money, paper, pencils, etc. An important task is the mail system. A game assistant is needed to deliver the mail. Altogether, the preparations for one run of Remodel generally take at least half a day if one has run the game before.

2.5 Further adjustments to the game

Lately we have been using a Local Area Network for the communication between participants. The results are very positive. Managing the game was generally a hectic job which use of the network made much easier. However, this way of playing necessitates many arrangements concerning computer hardware, connections, etc.

At the end of the game participants often get into a mood of trying to beat the computer jointly. In these circumstances the game manager has to terminate the game. A further adjustment of the game might therefore be to further increase the number of companies or to provide for more actors outside the corporations who could enhance the dynamics of the game, for example environmentalists, a second government agency (which, for example, aims to promote new technologies), an independent consulting firm and so on. This would, of course, make the game more

* We acknowledge the efforts of Patrick Jharap for helping to adjust the software for this version.

realistic, but also more complicated. The preparation time needed would increase and practical barriers might be put up.

We are currently working on an Internet version of Remodel that provides a remote participation facility and includes more actors.

3 LEARNING FROM REMODEL

The game Remodel, in its various forms, has been run about 25 times, generally with 15 to 22 science and engineering students as participants. In general, role inclusion of the participants is very high: problems caused by participants who withdraw from the game virtually never occur. In the game motivation is high; the participants very soon take various initiatives that fit into the game, without being given any incentive to do so.

The game makes a profound impression on its participants. Although we did not perform any long-term evaluations of learning effects, it is our impression that, even after more than a year, most of the participants are able to recall exactly what happened during the game.

Students strongly prefer learning from their 'own experiences' to traditional teaching. The main learning effects in catchwords are: 'delegating responsibilities', 'decision-making under uncertainty', 'corporate responsibilities versus political convictions' and 'government- industry interdependencies'. We will deal with these issues separately:

Delegating Responsibilities

Most executives have problems in delegating responsibilities to their R&D and Marketing Departments. They often try to re-calculate the recommendations given by these departments, which is futile since they do not have the detailed data required for such calculations. In the first rounds of the game, and also during later rounds if business is bad, the written correspondence often consists of demands for these data. Because of the time pressure in the game (decisions will have to be made at the end of the 'year', just as in real-life), there is simply no time for recalculation, even if the data are received and understood. Confidence in each other's capacities is also undermined by confusion of tongues or plain incomplete recommendations - both factors are aggravated by time pressure. The marketing and R&D departments sometimes lose their trust in the executive board if their recommendations are not followed blindly. This is also a sign of fear of delegation; the executives have an overview over Marketing as well as R&D requirements, something that is not understood by these departments - especially if things go wrong for the company. Rumours instigated by the journalist often aggravate mistrust; for example, bribing is allowed so long as the game managers (as presidential authority) do not know about it; the journalist can spread rumours about it. Bribing does occur in the game.

Probably, this problem concerning delegating responsibility is specific to working with science and engineering students: their training consists of learning how to work out things for themselves. They do not learn how to allow others, better trained or equipped, to work out things for them. Dealing with deadlines

neither forms part of their training; participants often expect the game manager to delay the game if they are not ready. Naturally this is refused. This attitude is probably caused by the academic way of dealing with problems: you simply take the time needed for a solution that meets the scientific criteria. The game teaches its participants to work towards a solution that can be reached with the means given, and within a given period.

Decision-making under uncertainty

A few aspects of decision-making under uncertainty are closely linked to the problems of delegating responsibility; each department has to base its decisions on its own - limited - data. The main aspect of understanding the problem of making decisions without complete scientific knowledge comes up during the game, when the EPA gets new reports (from the computer, or maybe even through the newspaper) on the state of the environment. The companies never know how long EPA measures will remain unchanged. Nor do their own R&D departments have a complete overview of the state of the environment. The competitive element between the two companies increases uncertainty; when the other company develops a new product and successfully launches it on the market there is no reason why the EPA should not ban the CFC for which it is a substitute.

Corporate responsibilities versus political convictions

In the evaluations we ask the students if they developed any explicit (corporate) environmental policy. Almost always the answer is 'no'. The environment is seen as a cost factor; the company's mission is to make profits. Some companies had environmental programs as a derivative of economic motives, for example in order to have a strong negotiating position towards the EPA (the EPA can mediate to the President to get financial support for 'green product development').

Interdependency of government and industry

From time to time it turned out that the EPA had been bribed by company money; a civil servant's salary is lower than that of the average company employee. There are, however, also serious discussions, in which subsidies or loans can be given. In one game the participants even decided to organise a scientific conference with both companies and the EPA.

Other learning effects

Elements of a social ('prisoners') dilemma also emerged: when one company is pro-active and the other is reactive towards the environmental effects of CFCs the latter will gain more money when there is no strict environmental legislation. This happens because the latter company does not have to invest or pay levies on its CFC products. Only if both companies decide to act, they are both better off than in a situation where neither acts - provided that investing now is cheaper than paying levies in later years.

There are some social lessons for the participants of the game too. In most games, the executives keep their own salaries higher than those of their sub-ordinates in marketing and R&D. However, inside each room, the wages were often equalled. Therefore, even the secretary of the executive board generally earns

more than the marketing chief. There are not many complaints about this situation. From time to time executives can be seen to give away some of their money. Generally, however, they themselves eat most expensive. In one case, an excessive executive board lunch (while others could only pay for one sandwich) led to a strike. The lesson, however, seems to be that solidarity is substantial in the same room, but...

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CONCLUSION

The future of simulation games: Issues and challenges

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Abstract

Issues and challenges for the future development and application of games for production management are discussed, based on the results of a group work session at the closing of the workshop. A general model is used to discuss trends in industry and to identify key elements of designing, operating and validating simulation games. New types of simulation games may contribute to meet these trends. However, it will require that new focal areas be included and new elements be developed. The paper will discuss the direction of this development.

Keywords

Simulation games, facilitator role, debriefing, modeling, validation

1 INTRODUCTION

In an effort to identify issues and challenges for the future development and application of simulation games in the area of production management, we have prepared a model which identifies some of the key elements of designing, operating and validating simulation games, cf. Figure 1.

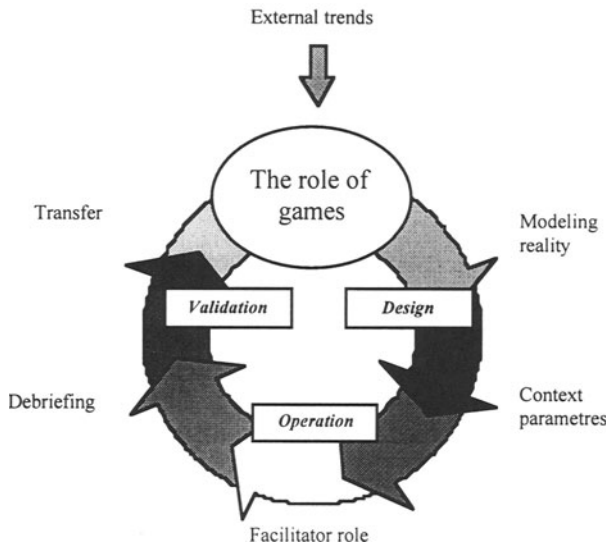


Figure 1. A model of key elements of designing, operating and validating simulation games.

We start by looking at trends in industrial enterprises to identify challenges for future roles of games, e.g. which areas and topics should be addressed, which qualifications are needed, and which learning processes should be emphasized.

Thereafter, we discuss the main elements of designing, operating and validating simulation games, respectively modeling reality and some context parameters for the games, the facilitator role, debriefing, and validation as well as transfer of the learning results.¹

2 TRENDS IN INDUSTRIAL ENTERPRISES AND THE ROLE OF GAMES

We have identified three trends in the conditions for industrial enterprises as well as in the ways universities generate and transfer knowledge, which in particular may affect the development of simulation games.

¹This chapter has been prepared on the basis of a group discussion held at the end of the workshop. Mari Ventä and Juha-Pekka Mäkelä from Helsinki University of Technology have recorded and summarized the discussion. A draft version of the chapter has been circulated to the participants for comments and suggestions. The authors hope that the chapter captures the essential points of the discussion among the participants.

2.1 Globalization

In the past decade there has been an increased internationalization of trade. This has also led to an increased globalization of product development and formation of global networks of production facilities, enabled through the rapid advancement of telecommunication technology. This development calls for a better understanding of the operation of complex business networks. Could simulation games be developed to address these challenges?

At universities, international networks and cooperation will proliferate, and the concept of the IT-enabled virtual university will become substantiated. Simulation games offer several ways of stimulating learning and training in a global setting.

2.2 Integration

The increased pressure in industry to shorten delivery time and, yet, be able to increase quality and productivity has strengthened the need to integrate the work across disciplines and functions. New organizational forms and working modes have to be introduced and practised. This suggests that the focus of simulation games be directed towards integration of disciplines and functions, and also, as a consequence, address holistic thinking.

Also at universities, integration will be a key issue in the near future. First, students should be trained to meet the challenges of industry, e.g. to address technical and social issues, to integrate various disciplines and functions (e.g. mechanical and electrical engineering design, marketing, production engineering, organizational and economic aspects). Second, there is a growing demand for combining theory and practice at universities.

Could simulation games be used as a vehicle for integration both in industry and universities? For example, could customers be involved in a game to create a better understanding of customer needs; could practitioners play with students to offer opportunities for mutual exchange of ideas and experience; or could a game prepare students to cope with future integrated production systems?

2.3 Change management

Increasingly industrial enterprises will be met by a quest to be able to change their operation with great speed and precision. Change will be the norm. In some instances an incremental improvement effort is sufficient to cope with external challenges. But in other situations a more radical re-engineering is warranted, e.g. a shift in the basic production management principles. Increasingly, we believe that there will be a need to train students to engage in innovative engineering design efforts.

In addition, in many countries there is a wide-spread appreciation of the need to involve employees not only in the daily operation, but also in development activities. This will require that employees be actively involved early in the change process to create increased awareness of the need to change. Employees should be

empowered to take initiatives in the intricate mutual interplay of actors and systems which will characterize the modern industrial organization.

Simulation games have already demonstrated a capability to help create a common understanding of present processes, which is the critical starting point of any change project. The globalization and integration trends constitute challenges for the development of simulation games that efficiently support the creative experimentation and innovation of future production systems.

2.4 Challenges for the role of games

The indicated trends of industrial enterprises point to new roles which simulation games may play. New opportunities are:

- Games to illustrate international networks of vendors, production facilities and customers
- Games to train in holistic thinking
- Games to create an interaction of disciplines and functions, and industrialists and students, and to stimulate integration
- Games to stimulate creative thinking
- Games to illustrate future production systems
- Games to empower employees to take initiative in the complex setting of industrial enterprises

The general objectives of a game include learning, creating a good cooperative attitude, sharing tacit knowledge, understanding and developing patterns of organizational behaviour, changing personal behaviour, enhancing creativity, and enabling communication. To fulfill these objectives and to become a useful development methods, games have however to be carefully designed and facilitated.

3 MODELING REALITY

A key issue of modeling is the capturing of complex phenomena in such a way that it can be communicated to others. If the model is too detailed and complex, very few will take the time and effort needed to understand the model. On the other hand, if the model is very simple and general, it does not reflect the nature of reality.

The same argument holds for simulation games. Experience shows that a game does not need to give a perfect picture of reality. The challenge is to select an appropriate focus for the game, and extract and model the essential properties of reality which are sufficiently rich to reflect reality for participants. Apparently it is more important that players experience a familiarity with the simulation environment and context than that the game is a true replica of reality.

With a view to the subsequent transfer of game results to reality, it is important that industrialist players can identify their own professional situation (company, department, market ...) in the game, or that students accept that the game portrays

a realistic industrial situation. Several contextual factors influence the design of a game and offer opportunities as well as constraints.

3.1 Time and cost

In the past decade there has been a pressure to reduce the time necessary to run a game. Previously, a game run in an enterprise would typically last for two or three days, whereas the time limit for a game today more likely is one full day. At universities, the time slots available for lectures and exercises are often difficult to change.

Cost constraints are also imposed, especially at universities, not only with respect to the acquisition of a game, but also the manpower needed for running the game.

3.2 Technology

Modern technology, in particular information technology, offers great possibilities for playing simulation games in new ways; for example telecommunication networks, virtual reality and graphical presentations of data.

However, there is a risk of shifting focus away from the game itself when advanced technology is used. On the one hand, technology may be instrumental in visualizing the game model and its dynamics. But, on the other hand, there is a risk that technology may hide some aspects of the model that previously were made visible in the manual games; e.g. the face-to-face discussion between players, or the concrete experience from physically doing things in the game, which are essential for the externalization of tacit knowledge.

Using simulation games to demonstrate the operation of an international network organization represents a major challenge to simulate activities that the players cannot see with participants they do not know. Is telepresence sufficiently interactive, emotional and close? Such issues need to be addressed.

3.3 Participants

The motivation and attitude of the participants is of course important for the success of a simulation game. Some games use PC software or standard production management systems applications, which require prior knowledge of participants in order to enable them to concentrate on the game. However, many games have no pre-requisites with respect to prior knowledge, which will allow the game to be run with different categories of employees from top managers to workers on the shop floor. This may be more frequent in the future, as a means to stimulate the vertical communication and learning in industrial organizations.

Often employees are not challenged to be creative in their job and consequently may be reluctant to engage in such an activity in a game. However, simulation games provide a setting with a mixture of fun and sincerity in which it is safe to make experiments without losing face. The need to stimulate creative and innovative behaviour mentioned above may be included in most games, in enterprises as well as in universities.

4 FACILITATING AND DEBRIEFING SIMULATION GAMES

4.1 Facilitator role

The important role of the game facilitator has perhaps not been sufficiently stressed in the past. It is very much different from the traditional role of a teacher or lecturer, because the facilitator must be sensitive to the behavioural processes during the game and let the participants live the situations of the game like in reality. The facilitator should also be capable of intervening when needed, e.g. to stop the game for a time-out. During debriefings important incidents should be discussed and reflected upon, and theoretical knowledge should be presented when appropriate to enlighten the discussion. Facilitating requires special talents that should be consciously developed and trained.

At universities the role of teachers is likely to change in the future from that of a lecturer to the role of a coach, as students will become more involved in project work and self-driven learning activities. We see a general trend at universities away from focusing exclusively on theoretical knowledge towards also including application aspects, and even training proficiencies in coping with industrial issues - individually and collectively.

This shift of teachers' role is conducive to letting more teachers be trained as facilitators. In general there is a need to put increased emphasis on training of teachers to be proficient in the role of a coach or a facilitator.

Concerning games in enterprises, the question whether to use an external or an internal facilitator has been discussed at length. However, there is general agreement that it is important that the facilitator and the game fit together.

As already pointed out, there is a need to develop games which support creative thinking. However, this puts pressure on the facilitator. For example, in cases where the game includes process improvement aspects, the facilitator should know the game well enough to guide the participants in their experimentations for new process designs. If the actual game is not capable of accommodating innovative solutions in a certain area, the facilitator should direct the participants in other directions, and maybe save the original ideas to be discussed in debriefings. Participants may become quite disappointed, if the game cannot allow them to include their creative ideas, especially if the game facilitator has encouraged creativity.

4.2 Debriefing

Ordinarily, the periods during which the game is run are considered the most essential and consequently should take up most of the time. An alternative view states that the running of the game merely is a necessary step to provide a common experience for the debriefing period. In any case, the debriefing is essential for achieving the objectives of the game.

Some of the elements of debriefing include:

- Analysis of incidents of the game session, including exchange of information to create a commonly shared understanding of what went on
- Reflection on the meaning of the incidents to contribute to a collective learning process
- Transfer to own situation, e.g. by comparing the incidents in the game with those of the participants' daily work
- Development of new solutions, either an improvement on the basis of the current system, or an innovative solution.

If the game is run at different geographical locations, special means should be adopted to ensure a collective learning process during the debriefing sessions, e.g. interactive video, and joint exercises for analysis and improvements.

5 VALIDATION AND TRANSFER

The methodology of design and operation of simulation games has a weak point, namely validation. The game model itself as well as the results of the game compared to the formulated objectives need to be validated. Also the transfer of the experience gained and the learning taken place to the reality of the participants have to be followed up and researched.

At universities we need better methods for assessing under which circumstances a simulation game may lead to more effective and efficient learning processes compared with lectures, case studies and projects, and which combinations should be recommended.

Especially in the field of simulation games for production management, the systematic validation of the games run is often neglected. As a consequence, evaluation methods are not well developed, and will require a great effort with respect to data collection and analysis. Development of new types of games for international production networks and for stimulating creativity will make it even more difficult to define appropriate measures of success. Further research is needed in this area.

The simulation game itself may not change anything. Only when the results are transferred to the situations of the participants, a change in attitude, knowledge and behaviour may take place. Several elements affect this transfer, e.g. the way in which the role and objectives of the game are defined, the game model and its realization, as well as the debriefings.

6 CONCLUSION

Industrial enterprises face the trends of increased globalization and integration across disciplines and functions. A more effective and predictable change management is needed which requires creative thinking, and continuous organizational learning.

Simulation games may contribute to meet these challenges both in industry and at universities. However, it will require that new focal areas be included in the simulations, such as international network organizations and new technology. New challenges must be coped with when designing, operating and validating games so that they meet the requirements for efficient learning and creativity. For example, we have pointed out that new ways of running the simulations and carrying out the debriefings in a geographically dispersed group of participants will call for the application of new telecommunication means.

We hope that a continuing development effort from researchers, designers as well as users of the games results in new innovative simulation games and methods to enhance experimental learning and innovation in production management.

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